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ELEMENTS

OF

CHEMISTRY,

IN WHICH THE

RECENT DISCOVERIES IN THE SCIENCE ARE INCLUDED,

AND

ITS DOCTRINES FAMILIARLY EXPLAINED

ILLUSTRATED BY NUMEROUS ENGRAVINGS,

AND

DESIGNED FOR THE USE OF SCHOOLS AND ACADEMIES.

BY J. L. COMSTOCK, M. D.,

MEM. CON. M. S.; HON. MEM. R. I. M. S.; AUTHOR OF NOTES TO CONV. ON CHEMISTRY; AUTHOR OF GRAM. OF CHEMISTRY; ELEM. MINERALOGY; NATURAL HISTORY OF QUADRUPEDS AND BIRDS; NATURAL PHILOSOPHY, ETC.

REVISED STEREOTYPE EDITION.

NEW YORK:
PUBLISHED BY PRATT, WOODFORD & CO.
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FOR THE

THIRD STEREOTYPE EDITION.

THE circulation of this work requiring new stereotype plates, (for the third time,) the author has again, with much labor, revised the whole, and added such new matter, and new illustrations, as the rapid advance of chemical science appeared to demand. Nearly all the old figures which remain have been re-engraved, and a large number of new ones added, so as to make the illustrations and embellishments, it is believed, equal to those of any work of the kind in market.

The cuts have either been drawn by the author, or selected from foreign works, and chiefly from Fownes, Graham, Campbell, Mitscherlich, or Muller. The changes in the text required much labor and attention, in order to make the terms correspond with the present chemical nomenclature. In many instances, where the new terms were such as not to be readily comprehended, the old terms are allowed to remain, with the new ones as synonyms. This was thought to be the most convenient plan for the pupils, since this edition may now be employed in classes with the former one.

The new matter will be found chiefly in the elementary parts of the work, where many changes have been made, and many new illustrations added.

HARTFORD, CONN., *April*, 1853.

PREFACE.

It is hardly necessary for the author of the following volume to make any excuses for its publication, since, notwithstanding the multiplicity of books on the same subject, there seems to be none which are exactly adapted to the object for which this is principally designed. The Conversations on Chemistry, and the works of Parke and Joyce, besides the interlocutory form in which they are written, are objectionable, in not containing the recent discoveries and improvements in the science; and the volume of Dr. Turner, though free from these objections, is too large for the use of schools and academies.

In this volume, it has been the intention of the author not only to avoid these objections, but, at the same time, to explain the elements and doctrines of the science in sufficient detail, to give a competent knowledge of its several parts, and in such language as can be understood by those who will but read the book attentively, and pursue the subject in course.

It appears to the writer, that in teaching Chemistry to youth, its elementary parts have not been sufficiently insisted on at the beginning. Of all the sciences, this is the complete, in respect to its language, the order of its arrangement, the succession of its subjects, and consequently, in the facility with which it may be learned. But from these perfections, arises the absolute necessity of becoming well acquainted with its first principles, before the student can derive and retain any useful knowledge from its study. The nomenclature of chemistry, the laws of affinity, and the doctrine of proportions, are far more necessary to a proper knowledge of this science, than is a knowledge of mathematics to the study of astronomy. The cause of an eclipse, or the reason why the complicated motions of the earth should produce a change of seasons, can be fully understood without the use of mathematics. But without a knowledge of affinity, and proportions, the decomposition of a salt, or the formation of a definite compound, are absolutely incomprehensible phenomena; nor can they be explained without a previous acquaintance with the peculiar language of chemistry.

It is from a conviction of the importance of first principles in learning this science, that the author has devoted so much attention to the imponderable agents, attraction, affinity, and galvanism, and to the explanation of definite proportions and chemical equivalents.

The doctrine of definite proportions, being now universally adopted, forms one of the fundamental principles of chemical science. And whether the theory of atoms, which accounts for the facts on which this doctrine is founded, be true, or false, the doctrine itself will ever maintain its integrity, its elements being nothing more than the expression of facts which experiment and analysis have developed. The subject of proportions, independently of its relation to theory or practice of Chemistry, is highly curious, and of uncommon interest, both to the naturalist and the moral philosopher. To the first it shows, that the laws of nature are equally inherent and efficient, in dead and in animated matter, and that the effects of these laws are as peculiar and distinctive in the formation of chemical compounds, as they are in the production and habitudes of the different races of animals. To the moralist, this subject teaches, that nothing has been formed by the fortuitous concurrence of atoms, but that even the "stocks and stones" bear the impress of creative agency and design — that the air he breathes, and the water he drinks, are formed of invariable proportions of certain elements, and that these compounds are so precisely adapted to his nature and wants, that the least change in the proportion of their constituents would inevitably effect his destruction.

Besides the charms which this subject presents to the reflecting student, the composition of compound bodies, in recent books of chemistry, is expressed in equivalent numbers, and therefore can not be understood without a knowledge of the doctrine of proportions. The author, therefore, before the description of each element and compound, has affixed to its name, at the head of the sections, its combining number, or atomic weight. By this arrangement, the pupil, at a single glance, becomes acquainted, not only with the scientific, and common names, but also with the composition and proportions of all the compounds described.

In respect to the authorities which have been consulted in the composition of this work, the principal are, Dr. Thomson, Dr. Henry, Sir H. Davy, Mr. Gray, Dr. Ure, Mr. Accum, Mr. Faraday, the Library of Useful Knowledge, the Journal of the Royal Institution, Silliman's Journal, and Dr. Turner.

Of the work of the latter author, free use has been made, his arrangement of subjects, with some variations, having been adopted, and his exposition of the doctrine of proportions carefully consulted. The work now offered, is not, however, to be considered as a servile compilation; the former experience of the author as a lecturer, and his habit, for many years, of analyzing various substances, having given him opportunities, not only of verifying the deductions of others, but occasionally of making new experiments for himself.

Hartford, Conn.

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hydrogen, a quantity of water will be formed. This is called *synthesis*, or the recomposition of water from its elements. Thus, all knowledge of this science is obtained by experiment.

As a science, chemistry is intimately connected with a great variety of natural phenomena. All satisfactory explanation of the causes of rain, hail, dew, wind, earthquakes, and volcanoes, have been given by the aid of chemical knowledge. The phenomena of respiration, the decay and growth of plants, and the functions of the several parts of animals, are also explained in a satisfactory manner, only by the aid of chemistry.

3. As an art, chemistry is connected, more or less intimately with nearly every branch of human industry, and particularly with agriculture and manufactures. In its application to agriculture, chemistry furnishes the most direct and certain means of ascertaining what a barren soil wants to make it a fruitful one, and also what ingredient any soil requires to best adapt it to any given kind of produce. Many of our most common and useful articles are manufactured entirely by chemical processes. The making of soap, glass, bleaching salts, the several kinds of acids, and almost every kind of medicine, depend wholly on the manipulations of chemistry. The art of the potter, iron-smith, tanner, sugar-maker, distiller, brewer, vintner, paper-maker, and painter, are also connected in various degrees with chemistry.

4. NUMBER OF CHEMICAL ELEMENTS.—We have already seen that an *element* is a body or substance which has not been decomposed. Formerly, the number of such bodies known to chemists were quite small, but the advance of science and the skill of practical chemists have shown, that many articles once considered elements were really compounds; having, many of them, by new methods of manipulation, and new re-agents, been resolved into several elementary bodies. Within the last ten years the number of known elements have been increased from about fifty to upward of sixty. [*See Table of Elementary Substances.*]

Natural objects may be separated into two great divisions, or classes, viz.: Imponderable agents and Ponderable bodies.

What is synthesis? What are among the natural phenomena which chemistry explains? What are among the most important arts which derive advantage from chemistry? What is said of the number of elements? How are natural objects divided?

PART I.

CHAPTER II.

IMPONDERABLE AGENTS.

5. The imponderable agents are Light, Caloric, or Heat, Electricity, and Galvanism. These are called the imponderable agents, because they possess no appreciable weight. The investigation of many of the properties of these agents, and particularly those of light and attraction, belong to the several departments of natural philosophy, but they each possess properties also, which are strictly chemical, and it is these properties only, which it is proposed here to examine.

CALORIC.

6. Heat is the sensation which one feels when he touches a body hotter than the hand; and this sensation is caused by the passage of *caloric* from the hot body to the hand. Thus caloric is the cause of the sensation which we call heat, and heat is the effect of the passage of caloric into the hand. Caloric, then, is the *matter* or *principle* of heat, while heat is the sensation produced by the transfer of this principle to the living system, from some body hotter than itself.

Caloric is imponderable; that is, there is no appreciable difference in the weight of a body, whether it is hot or cold.

This principle seems to be present in all bodies, nor is there any known process by which it can be separated from any substance. For, since heat constantly passes from the hotter to the colder body, until every thing in the same vicinity becomes of an equal temperature, so if we take a substance at a temperature however low, and carry it to a place where the temperature is still lower, this substance will give out heat until its temperature becomes the same with that of the surrounding air. For instance, if a piece of ice at 32 degrees of temperature,

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What are the imponderable agents? Why are these agents called imponderable? When one touches a body hotter than his hand, why does he feel the sensation of heat? What is caloric? What is heat? How is it proved that caloric is imponderable? How is it shown that caloric is present in all bodies? What illustrations show that ice will emit caloric?

called *caloric of fluidity*, because, in the conversion of solids into fluids, a quantity of heat is absorbed which is not indicated by the thermometer, and which, therefore, becomes latent in the fluid.

The experiments of Dr. Black, in relation to this subject, are highly curious and interesting. These experiments prove, that if a pound of water, at 32 degrees, be mixed with a pound of water at 172 degrees, the temperature of the mixture will be intermediate between them, and therefore 102 degrees. But if a pound of ice at 32 degrees be mixed with a pound of water at 172 degrees, the ice will soon be dissolved, and then, on applying the thermometer to the water thus formed, it will be found at the same temperature that the ice was before the addition of the warm water, and therefore at 32 degrees, instead of 102 degrees, as before. In this experiment, therefore, the pound of hot water lost 140 degrees of caloric, which is employed in melting the ice, and which is not appreciable by the thermometer, but remains latent in the water. It follows, then, that a quantity of caloric becomes insensible during the melting of ice, which, were it free, or uncombined, would raise the temperature of the same weight of water 140 degrees; for, the ice being at 32 degrees, and the water at 172 degrees, at the beginning of the experiment, and the whole being at 32 degrees at the end, the water loses 140 degrees, being the excess of 172 degrees above 32.

12. It is well known, that if a piece of ice be exposed to the rays of the hottest sun in the summer, or if it is placed in a vessel over a fire, the temperature of the ice, or of the water flowing from it, will not be raised above 32 degrees, until the ice is all melted, when the thermometer placed in the vessel will instantly begin to rise. Those who have melted snow, or ice, for culinary or other purposes, are well aware how much more time and fuel it takes to obtain a vessel of boiling water from ice, than it does from the liquid itself. But this fact is readily accounted for by Dr. Black's experiment, since we have seen above, that 140 degrees of heat are first employed merely in converting the ice into water, and that this caloric does not raise the water one degree above the freezing point, or 32 degrees, until all the ice is melted.

13. This principle is of vast consequence to the world, and

How many degrees of heat become latent during the conversion of ice into water? How is this shown by experiment? What common fact shows that the temperature of water can not be raised as long as it contains ice?

particularly to the inhabitants of cold climates, where the ground is covered with snow and ice, a part or the whole of the year. In some northern climates, and particularly in Russia, the transition from the cold of winter to the heat of summer takes place within a few days, the ground being covered several feet deep with the accumulated snow of the winter. Now, were it not for the fact above explained, and did the snow and ice follow the same law, in respect to temperature, that we observe in some other bodies, this whole mass would be turned into water nearly as soon as the temperature of the atmosphere became above 32 degrees, and consequently the whole country would be inundated and destroyed by the flood.

But in consequence of the quantity of caloric employed in the liquefaction of the snow, the melting is gradual, and no such accident ensues. This is a striking instance of the wisdom and mercy of Providence toward man, though to most of the world it is unseen and unknown.

We have mentioned the melting of ice, as being the most familiar example, in most parts of our country, of the conversion of a solid into a fluid. But the principle holds with respect to the conversion of other solids into liquids, though the quantity of caloric required for this purpose varies with the substance.

From the experiments of Dr. Irvine, it appears that the following named substances vary in this respect very widely, and also very unexpectedly. Equal weights of each substance are supposed to be employed in the experiments: the degrees indicate the extent to which each would have been heated by the caloric of fluidity proper to it. Spermaceti, 145 degrees; lead, 162 degrees; bees-wax, 175 degrees; zinc, 493 degrees; tin, 500 degrees; bismuth, 550 degrees.

14. NATURE OF HEAT.—Of the nature of this universal and most important agent, there have been suggested two opinions, viz.: 1st. That it is material, or composed of particles of matter, though so nearly imponderable as not to be weighed by any means in our power. 2d. That it consists in nothing more than a quantity of matter pervading all space, and that its effects are produced by undulations. We can not here examine these theories, but only mention them that the student may

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What circumstances are mentioned under which the great quantity of caloric absorbed by melting ice, is a blessing to mankind? When the temperature of the atmosphere is above the freezing point, why does not the snow and ice instantly return to water? In melting, do other solids besides ice absorb a quantity of caloric not appreciable by the thermometer? What two opinions about the nature of heat?

understand more clearly some of the phenomena of heat which we shall mention.

7

15. DIFFERENT KINDS OF HEAT.—Some facts which we witness every day are curious illustrations of what might be considered as different species, or sorts of heat. Thus, the window glass which admits the light and heat of the sun into our rooms, are not at all heated thereby; the heat seeming to pass through their solid substance without difficulty, leaving none of its particles behind. But if the same glass be transferred to the front of a fire of the same temperature as the rays of the sun, the glass soon becomes so hot as to burn the hand. Such being the difference between natural and artificial heat in their effects, the one passing freely through transparent bodies which almost entirely intercept the other.

16. HEAT BY FRICTION AND COMPRESSION.—If two dry substances, whether hard or soft, be rubbed together, heat is the consequence. Savages, even, kindle a fire by rubbing two dry sticks together; and every one knows that the hand becomes warm by rubbing it on the sleeve of a garment. When air is suddenly compressed, it emits so much heat as to ignite various substances, of which an illustration is given by Fig. 16. In this case it is supposed that the caloric is forced out of the air by increasing its density, and thus diminishing its capacity for caloric, and on the same principle that friction converts latent, into free heat, by pressing the air along the surface rubbed. But Sir H. Davy succeeded in melting two pieces of ice, by rubbing them together in the vacuum of an air-pump, while the temperature where this curious experiment was made was below 32 degrees, showing clearly that at least an ice-melting heat was developed by the friction. It is difficult to reconcile the results of this experiment with the theory that the product of heat by friction and compression is owing to the diminution of capacity to retain caloric.

17. Pictet found that two pieces of brass rubbed together produced less heat than one piece of brass and another of wood, and that the heat was highest when two pieces of wood were used. The same philosopher found that solids only produced heat by friction, and that no change of temperature was produced when a solid acted mechanically on a liquid, or liquids, on each other, or when air or gas was forced ever so strongly on a solid, or liquid.

What are the effects of natural and artificial heat on glass? What is said about heat by friction and compression?

STEAM.

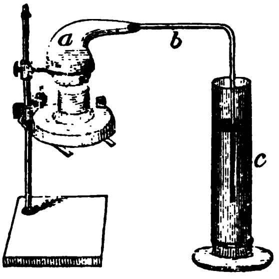
18. When water, or other liquids, are converted into steam, a large quantity of caloric is absorbed, which is not indicated by the thermometer, and which, therefore, becomes latent in the steam.

If a thermometer be placed in an open vessel of water, over a fire, there will be indicated a gradual increase of heat until the water boils, after which no increase of the fire will raise the temperature of the water another degree; nor does the steam, arising from a vessel of water which boils violently, indicate a greater degree of heat than the water itself, or of the steam arising from another vessel which boils moderately. The steam conveys away all the heat above 212 degrees of Fahrenheit's thermometer, which is the temperature of boiling water under the ordinary pressure of the atmosphere.

The quantity of caloric which combines with the water to form steam, is nearly 1000 degrees greater than that of the same weight of boiling water. In other terms, the caloric of fluidity in steam surpasses that of an equal weight of boiling water by nearly 1000 degrees. Consequently, there is nearly 1000 degrees of heat in steam which is not indicated by the thermometer, and is therefore latent.

19. BY THE APPARATUS, FIG. 1, THE LATENT HEAT IN STEAM BECOMES APPARENT.—The small glass retort, *a*, is kept boiling by means of a spirit lamp. From the retort, the tube *b*, bent at right angles, dips into cold water contained in the jar *c*, and by which the steam is condensed. Now, the heat absorbed from the fire, through the water, to form the steam, is given out to the cold water as fast as the steam is condensed. The cold water must, therefore, have its temperature gradually raised until it reaches 212 degrees, the boiling point, after which no more steam will be con-

FIG. 1.



Latent Heat of Steam.

Why can not water, in an open vessel, be heated higher than 212 degrees? How many degrees of heat does steam contain, which is not indicated by the thermometer?

densed, the water boiling in the jar, as well as in the retort. When this occurs the process must cease.

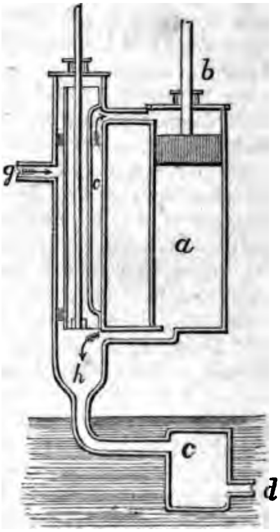
Now, assuming that the jar *c* contained eleven cubic inches of water at 32 degrees, at the beginning of the experiment, and thirteen inches at the close. at 212 degrees. then the water in the jar would have increased two cubic inches, having gained this from the condensation of the steam from the retort. The latent heat, therefore, contained in two cubic inches of water in the form of steam, has raised the eleven cubic inches in the jar from 32 degrees to 212 degrees. We may therefore, says Müller, (from whom this experiment is taken,) express the result of our experiment in the following manner. The amount of heat necessary to convert a definite quantity of water from 212 degrees into steam at 212 degrees, suffices to raise the temperature of a mass of water five and a half times greater, from 32 degrees to 212 degrees.

20. STEAM-ENGINE.—The mechanical details of the steam-engine must be looked for in other books, our object here being merely such a description as to enable the pupil to comprehend its principles.

This complicated machine consists essentially of a cylinder of metal, *a*, Fig. 2, in which works a solid piston also of metal, the rod of which passes air-tight through the stuffing box *b*, at the top of the cylinder. The piston is connected with the machinery to be put in motion, as the paddle-wheels of a steamboat, either directly, or by the intervention of an oscillating beam.

A pipe communicates with the interior of the cylinder, leading to a large vessel *c*, surrounded with cold water, and called the *condenser*. Into this a jet of cold

FIG. 2.



Steam-engine.

Describe the experiment of Müller to show the amount of latent heat in steam. Describe the principle of the steam-engine.

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boiling, when conducted in a tall, glass vessel, over an Argand lamp, may be minutely examined, and is both interesting and instructive.

It is found by experiment, that different fluids at the surface of the earth, boil at different temperatures, depending generally on the specific gravity of the fluid, and also, that the same fluid boils at various temperatures, depending on the degrees of atmospheric pressure. Thus, under the same pressure of the atmosphere, or on the level of the sea, water boils at 212 degrees; ether at 100 degrees; alcohol 173 degrees; nitric acid, of the specific gravity of 1,450, at 240 degrees, and water, saturated with sea salt, 216 degrees.

We may observe, that in these instances, the boiling of a fluid seems to follow a general law depending on its specific gravity. This is strictly the case in respect to the boiling point of sulphuric acid, which always requires a temperature for its ebullition in a direct proportion to its specific gravity.

Thus, according to Dr. Dalton, sulphuric acid, sp. gr. 1,450, boiled at 240 degrees, while that of sp. gr. 1,670, boiled at 360 degrees; that of 1,780, at 435 degrees, and that of 1,850, at 620 degrees.

The boiling point of a fluid is not, however, in all cases, to be estimated by its specific gravity, the fixed oils requiring much higher temperatures for their ebullition than other fluids of the same density. Thus, linseed oil boils at 640 degrees, though its specific gravity is less than that of water; and mercury boils at about 660, though its specific gravity is about fourteen times that of water.

That water, or any other fluid, will boil with a less degree ot heat, in proportion as the weight of the atmosphere is removed, may be readily proved by means of the air-pump, or by ascending up a mountain, where the air is less dense than it is on the level of the sea.

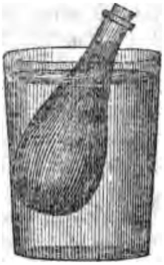
The most simple illustrations of this subject, with the air-pump, may be made by means of a small vessel of ether; for if this be placed under the receiver, and the air exhausted, the fluid will boil, or turn to vapor, during ordinary temperatures of the atmosphere. See Fig. 5.

On what does the boiling temperature of fluids generally depend? Why is the boiling temperature of water, saturated with salt, higher than that of pure water? What is said concerning the influence of specific gravity on the boiling temperature of liquids? Under what circumstances will water boil at a less temperature than 212 degrees? How may the pressure of the atmosphere be removed from a vessel of water, without the use of an air-pump?

24. TO MAKE WATER BOIL BY COOLING IT.—If a vessel of hot water, instead of the ether, be placed under the receiver and the air withdrawn from it, the water will continue to boil until its temperature is reduced down to 70 degrees.

In the absence of an air-pump, the same principle may be strikingly illustrated as follows: Adapt a good cork to the glass flask, Fig. 3, so as to make it air-tight; put a gill or two of water into it, and apply the heat of a lamp until it boils. After it has boiled for a short time, introduce the cork, and at the same time take the flask from the fire. It will continue to boil for a few minutes after its removal. When the ebullition has ceased, it will boil again violently on plunging the flask into a jar of cold water, as seen in the figure. On taking it out of the water the ebullition will cease, but will instantly recommence if again plunged into the water; and this may be continued until the flask is nearly cold.

FIG. 3.



Boiling Water.

In this experiment, the boiling is continued in consequence of the partial vacuum which is occasioned by the condensation of the steam with which the flask was at first filled. If the flask be taken from the vessel of cold water, and plunged into one of hot water, the boiling will instantly cease, because the heat will convert a portion of the water in the flask, which had been condensed, into steam, and thus the partial vacuum, which had been formed, will be filled with vapor, the pressure of which will prevent further ebullition.

This principle is beautifully illustrated by the fact, that the higher we ascend from the surface of the earth, the lower will be the temperature at which water boils. The reason is obvious; the pressure of the atmosphere diminishes in proportion to the ascent, and the boiling temperature sinks in proportion as the pressure is removed.

25. PHENOMENA OF BOILING ON A MOUNTAIN.—Upon this principle is constructed the *thermometric barometer*, which indicates the elevation of any place above the level of the sea, by the temperature at which water boils at that elevation. By experiment, it has been found that a difference in elevation,

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Why will the water in a vessel, Fig. 3, be made to boil by cold, and cease to boil by heat? Why does water boil at a lower temperature on a high mountain, than on the level of the sea? What instrument is constructed on this principle?

amounting to nearly 520 feet, makes a difference of one degree in the boiling point of water. A traveler, therefore, who ascends a high mountain, may ascertain nearly his elevation by the temperature at which he finds his tea-kettle to boil. Thus, Saussure found that at a certain station on Mount Blanc, water boiled when heated to 187 degrees. This being 25 degrees less than its boiling point at the level of the sea, allowing 520 feet for every degree, would give an elevation of 13,000 feet. This method can not, however, be very accurate, since the weight of the atmosphere at the same place varies at different times about three inches of the barometric guage. [*See Natural Philosophy, article Barometer.*]

26. EVAPORATION.—During the process of ebullition, there is a rapid formation of vapor, attended by more or less commotion in the liquid. Evaporation also consists in the formation of vapor without heat, but the process is so slow as not to occasion any visible commotion in the fluid. Evaporation takes place, even during the coldest seasons, while ebullition requires various degrees of heat, or at least the removal of atmospheric pressure.

To prove that evaporation takes place at ordinary temperatures, nothing more is necessary than to expose a quantity of water to the open air in a shallow vessel, when the fluid will be found gradually to diminish, and finally to disappear entirely. There is, however, a great difference in the rapidity with which different fluids evaporate, and in general it is found that those whose boiling points are lowest disappear most rapidly. Thus, ether and alcohol evaporate much more rapidly than water.

The chief circumstances which influence evaporation are, extent of surface, and the state of the atmosphere in respect to temperature, moisture, and dryness.

As evaporation takes place only from the surfaces of fluids, it is obvious that its rapidity must, under equal circumstances, be in proportion to this extent of surface. Thus, a given quantity of water will evaporate four times as soon from a vessel two feet square, as it will from a vessel of one foot square. In respect to temperature, it hardly need to be remarked, that fluids evaporate more rapidly in warm than in cold situations,

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How may a traveler, who ascends a high mountain, ascertain nearly his elevation by the boiling of a tea-kettle? What is evaporation? How is it shown that evaporation takes place without the aid of heat? What relation does there seem to be between the boiling point of a fluid and its evaporation? What are the chief circumstances which influence evaporation?

and that the process is hastened in proportion to the degree of heat employed.

Fluids evaporate much more rapidly in a dry, than in a damp atmosphere. Even when the season is cold, if the air be dry, this process goes on rapidly, while it is comparatively slow during the warmest seasons, if the air is already saturated with moisture.

As evaporation consists in the formation of vapor, and the subsequent removal of successive portions of the evaporating fluid by the air which comes into contact with its surface, it is obvious that the process must be more rapid in a current of air, than it is in a place where the air is still. And hence, we find by experience, that evaporation is more rapid in the open air than in the house, and that, under equal circumstances, is more speedily effected during a strong wind.

27. STEAM ABSORBS CALORIC.—We have already explained, that one of the peculiar circumstances attending the formation of steam, is the large quantity of caloric which it absorbs and carries away. Now it appears, by experiment, that the conversion of fluids into vapor always requires large quantities of caloric, which becomes latent in the vapor, however slowly the process is carried on, and hence, under ordinary circumstances, evaporation, by conveying off the heat, has the effect of generating cold. To make this fact sensible, by experiment, we h[illegible] only to pour a little ether on the hand, when a strong sensation of cold will be felt during its evaporation. When our clothes are wet by a shower of rain, we feel cold for the same reason, but the sensation is less strong, because the evaporation of water is not so rapid as that of ether.

It has been explained that water boils at a lower temperature, in proportion as the pressure of the atmosphere is removed. For the same reason, evaporation under equal circumstances, is most rapid when the weight of the atmosphere is removed, as under the exhausted receiver of the air-pump.

The cooling effects produced by the evaporation of water in the open air are not strikingly apparent, because the process is comparatively slow, and, therefore, the quantity of caloric carried away from a body in any given time, is but little more than it receives from surrounding objects. But when water is placed

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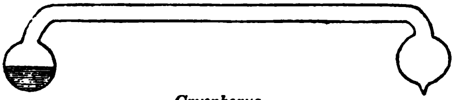
Is evaporation most rapid in hot or cold weather? In what does evaporation consist? Why is evaporation more rapid in the open air than in the house? What is said concerning the latent heat of vapor? How is cold produced by evaporation? Does the pressure of the atmosphere influence this process? Why does not the evaporation of water from the surface of the earth produce intense cold?

in a vacuum, its evaporation is very rapid, and did not the vapor from it fill the vacuum, and thus prevent further evaporation, the heat would be carried away so rapidly as soon to turn the water to ice.

FIG. 4.

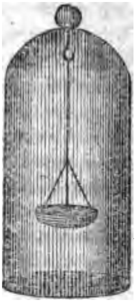


Cryophorus.

28. Cryophorus.—This curious effect is produced by means of an instrument invented by Dr. Wollaston, and called the *Cryophorus*, or *Frost-bearer*, Fig. 4. It consists of two glass balls, as free from air as possible, and joined together by a glass tube. One of the balls contains a portion of distilled water, while the other parts of the instrument, which appear empty, are full of aqueous vapor, which prevents the further evaporation of the water, by the pressure the vapor exerts on it. But when the empty ball is plunged into a freezing mixture, all the vapor within it is condensed; and then the evaporation becomes so rapid from the water in the other ball, as to freeze it in a few minutes. To make this experiment succeed, the tube should be a yard long, the balls holding about a quart each. The same effect on water will be produced by the evaporation of ether under the exhausted receiver of an air-pump.

29. To freeze water by evaporation.—This experiment may be conveniently made by placing a little water in a glass cup, and covering it with ether, after which suspend the cup within the receiver of the air-pump, as shown at Fig. 5. On exhausting the receiver, the ether will boil, in consequence of its rapid evaporation, and in a few minutes the water will be frozen.

FIG. 5.



Evaporation.

Evaporation takes place constantly, from the surfaces of our bodies, and it is owing to this circumstance that men are enabled to undergo exercise during the heat of summer. In general, the more violent the exercise,

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How may the evaporation of water be made so rapid as to turn itself into ice? What is the instrument, Fig. 4, called? How may water be frozen by the evaporation of ether? From what provision of nature are we enabled to use violent exercise in warm weather?

the greater is the quantity of perspiration, arising from the surface, and consequently the greater the quantity of heat carried away. In this manner nature regulates the heat of the system, and during health sustains the equilibrium of animal temperature. Whenever this exhalation from the skin is suppressed, which only results from disease, the temperature of the system rises, and fever succeeds. In some cases of this kind, the heat of the human body exceeds that of the standard of health by seven or eight degrees.

The natural temperature of the human body in health, is about 98 degrees, and whenever the heat of summer is equal to that of the body, it becomes exceedingly oppressive. The least exertion then brings on copious perspiration, which, indeed, prevents the immediate consequence of a higher animal temperature, but which is generally succeeded by languor and debility.

30. **Animals resists heat and cold.**—It is a wonderful fact, that the living animal has the power of resisting both heat and cold, and of maintaining its own temperature, whatever may be the temperature of the air or water in which it is immersed. Sir Joseph Banks, and Sir Charles Blagden, found by experiment that they could endure for a short time the heat of a room, the temperature of which was 264 degrees, that is, 52 degrees hotter than boiling water. These gentlemen found that their hands could not bear the heat of their watch-chains, or metallic buttons, but that their chests felt cold, and that the temperature of their bodies was not elevated above 98 degrees. In this room, eggs placed in a tin frame, were roasted in twenty minutes, and beefsteak was well cooked in about the same time.

CONDUCTORS OF CALORIC.

31. Some bodies have the power of conducting caloric much more rapidly than others. Thus, one can hardly hold a brass pin for a moment, in the flame of a lamp, without burning his fingers, while a piece of glass of the same size, may have one of its ends melted, without warming the other.

Bodies which are most dense are generally the best conductors. Thus the metals conduct better than stones; stones

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How does perspiration relieve us from the effects of excessive heat? What is the effect of suppressed perspiration on the temperature of our system? What is said of the power of animals to resist heat as well as cold? What striking illustration is given of the power of men to resist heat? What bodies are generally the best conductors of heat? Are the most dense bodies always the best conductors of heat?

better than earth; earth better than wood; and wood better than charcoal, cloth, or paper. But in particular cases there is no relation between the density of the body, and its power to conduct caloric. Thus platina is the most dense of the metals, and still it is one of the worst conductors among them; and glass is a worse conductor than many substances of less than half its density.

The following table presents the relative conducting powers of the most important metals, and a few other substances. The experiments by which these results were obtained, appear to have been conducted with much care. The substances were made into prisms of the same size and length, and while at one end the same degree of heat was applied to all, the temperature of each was seen by little thermometers, all graduated alike, the bulbs of which were set into the substance of each prism. By such means the following results were obtained:

Gold, . .	1,000	Tin, ...	304
Silver, ...	973	Lead, . . .	179
Copper, . . .	898	Marble, . . .	24
Platinum, . . .	381	Porcelain, . .	12
Iron, ...	374	Fine Clay, . .	11
Zinc, ...	363		

Solid substances, such as the metals, conduct caloric in all directions, whether upward, downward, or sideways, with nearly equal facility.

32. Porous bodies bad conductors.—Of all solids, those which are most porous conduct heat with the least facility. It is on this account that flannel is warmer in the winter than silk or linen. It does not so readily conduct away the animal heat. It is owing to the air, which loose spongy substances involve, that they resist the passage of heat better than those of a closer texture. Thus eider-down, and fur, make the warmest clothing, because they contain the most air among their parts, and for the same reason cotton batting is much warmer than the same weight of cotton cloth.

33. Warmth of snow.—The imperfect conducting power of snow also arises from the above cause. When newly fallen, a

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How are the conducting powers of different bodies ascertained? What kind of solids are the worst conductors of caloric? Why do loose spongy bodies conduct heat more slowly than others? Why is cotton batting warmer than the same weight of cotton cloth? In what manner does snow protect the earth from the cold of winter?

great proportion of its bulk consists of the air which it contains, as may be readily proved by the comparatively small quantity of water it makes when melted. Such a provision was designed for the benefit of man, in preventing the destruction of various products of the earth during the cold of winter. Farmers, in cold climates, always lament the nakedness of the earth during the winter, because many of their crops are in consequence injured by its severity. So great is the protecting effect of snow, that in Siberia, it is said, when the temperature of the air has been 70 degrees below the freezing point, that of the earth, under the snow, has seldom been colder than 32 degrees.

Our ordinary sensations every day convince us of the different powers of various substances to conduct heat. In the winter, the different articles in a cold room convey very different sensations to the hand. A pair of tongs will conduct away so much heat from the hand as to give a sensation of pain, while a piece of fur, or flannel, scarcely feels cold, and yet both are of the same temperature, when tested by the thermometer.

34. Conducting power of liquids.—Liquids communicate heat with considerable rapidity, though they conduct it so imperfectly that Count Rumford, after many experiments, concluded that they were absolutely non-conductors.

Liquids convey heat chiefly by a change of place among their particles. When a vessel of water is placed over the fire, that portion of the fluid nearest the heat having imbibed a portion of caloric, becomes lighter than before, and rises upward, communicating a part of its heat to the portions above. At the same time, that which is above sinks to the bottom of the vessel, and having obtained its portion of caloric, again rises, giving out a share to the surrounding fluid, like the former. In this manner does the water in the different parts of the vessel exchange places until the whole gains the temperature of 212 degrees.

35. Illustration.—The manner in which water circulates on the application of heat is readily made apparent as follows:

Into a thin glass flask, as shown at Fig. 6, containing water, pour a small quantity of insoluble powder, as pitch or rosin, which is nearly of the specific gravity of the water. When

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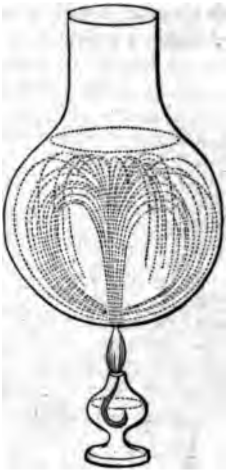
What is said to have been the difference between the temperature of the air, and the earth covered with snow, in Siberia? Why does a pair of tongs feel cold, when a piece of flannel or fur, at the same temperature, gives no sensation? How do liquids convey caloric?

placed over the heat of a lamp, the circulation of the particles will soon begin, rising in the center, where the heat is strongest, and falling near the sides, as shown by the figure.

Of course, the water rises and falls in the manner shown, without the particles, these only serving to make its motion more apparent. Even when the fluid boils, the same circulation will continue, if the heat of the lamp remains in the center of the vessel, because the heat over the flame is greater than at the sides of the vessel.

36. But though fluids convey heat chiefly by exchanging the places of their particles, yet they are not wholly without the power of conducting it in any direction.

FIG. 6.



Glass Flask.

Count Rumford, we have already stated, decided from his experiments that liquids were perfect non-conductors of heat; but Dr. Murray, and since him, other experimenters, have established the contrary doctrine. Dr. Murray's apparatus consisted of a vessel of ice, at the bottom of which was placed a delicate thermometer. The vessel was then partly filled with oil, at the temperature of 32 degrees, so as to cover the bulb of the thermometer; and nearly touching the oil, was suspended an iron cup, into which was poured a quantity of boiling water. In seven and a half minutes the heat from the water had raised the thermometer from 32 degrees to 37½ degrees, when it became stationary, and then gradually began to fall.

37. Dr. Hope placed water in a vessel of ice ten inches in diameter, and so contrived his apparatus, that a stream of cold water should circulate around this vessel, to prevent its conducting power from affecting the result. He then applied heat to the upper surface of the water in the vessel, and found by the indications of a thermometer placed in it, that the fluid conducted the caloric downward.

How does Fig. 6 illustrate the circulation of boiling water? Are fluids wholly without the power of conducting caloric? By what method did Dr. Murray determine that fluids were conductors of caloric? In what manner did Dr. Hope ascertain the same fact?

By such nice experiments only, has it been ascertained, that fluids conduct heat downward; while under all ordinary circumstances, they may be considered perfect non-conductors.

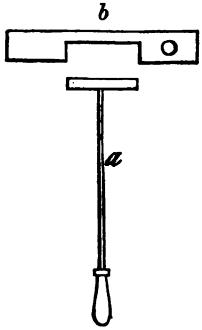
EXPANSIVE POWER OF HEAT.

38. One of the most remarkable properties of heat arises from the mutual repulsion of its particles, so that when it enters into other substances, it overcomes the cohesive attraction of their parts, making them less dense than before, and thus enlarging their dimensions. In general terms, therefore, heat expands all bodies. The ratio of this expansion, however, differs greatly in different substances. Thus, with the same increments of heat, fluids expand more than solids, and aeriform bodies more than fluids. There is also a considerable difference in the expansibility of different solids and different liquids; but the aeriform fluids, as air and the gases, all expand equally, with the same increase of temperature.

39. The expansion of a solid is readily proved, by adapting a piece of metal, when cold, to an orifice, or notch, and then heating it, when it will be found too large for its former place.

The cylindrical piece of brass, attached to the handle *a*, Fig. 7, is exactly fitted to the notch in the plate *b*, and also to the aperture through the plate, so that it will enter the notch, and pass through the aperture when cold; but when heated, even below redness, it will neither enter the notch, nor pass through the aperture. This proves that heat enlarges, or expands the dimensions of solids in every direction.

FIG. 7.



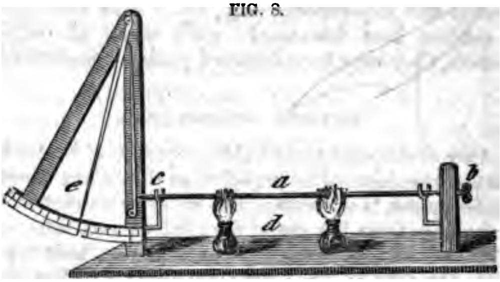
Expansion.

40. The relative degrees of expansion which different solids undergo, at high degrees of heat, are shown by an instrument called the *pyrometer*, one form of which is seen at Fig. 8.

A rod of any metal, *a*, is laid on the rests, and one end made to touch the immovable screw, *b*, while the other end touches the index *c*. The rod is then heated by the spirit lamps *d*, and

How does heat operate to enlarge the dimensions of bodies?

FIG. 8.



Expansion by Heat.

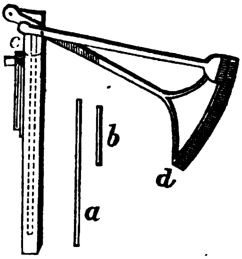
its comparative expansion is shown by the multiplied motion of the index, *e*, along the graduated scale.

In comparing different substances by means of this instrument, it will be necessary that all the rods should be of the same size and length, and that the heat of the lamps should be applied the same length of time.

From experiments made with this instrument, it appears that, in most instances, there is a relation between the expansion of the metals, and their fusibility, and in general, that those which are most easily fusible, expand most with equal increments of heat. Thus, lead, tin, and zinc, expand much more, by the same degrees of heat, than copper, silver, and iron, and the former are much more easily fusible than the latter.

41. Daniel's pyrometer.—The *pyrometer*, or *fire-measurer*, is an instrument which, by means of the expansion of some solid body, is made to indicate such high degrees of heat as are not within the range of the thermometer. That invented by Prof. Daniel, is the most simple and accurate. It consists of a black lead tube containing a bar of iron, which is fixed at the lower end, and is surmounted by

FIG. 9.



Pyrometer.

What bodies expand least, and what most, by heat? What is said of the equal expansion of air and the gases by heat? How is the expansion of a piece of metal shown by Fig. 7? How are relative degrees of expansion which solids undergo ascertained? Explain Fig. 8.

a plug of clay, or unglazed earthenware. The expansion of the iron by the heat, moves the clay, which acting on an index, shows the temperature. This is shown by Fig. 9, where *a* is the iron bar, longer than the blacklead tube, *b*, the plug of clay to be placed on its end, in the tube. The clay is secured by a piece of platina foil, so as to remain fixed in its place when the iron cools. The clay is shown at *c*, placed in the tube, and acting on the arm or hand *d* by means of a short lever, and showing by the index the degrees of heat, or the amount of expansion which the iron bar suffers.

The expansion of the metals by heat, is often turned to advantage by certain mechanics and artizans in their business. In constructing large cisterns for brewers, or other manufacturers, the iron hoops are made too small for the circumference of the vessel. They are then heated, and in this state driven on the vessel, and as they contract in cooling, the vessel is thus bound together more firmly than could be done by any other means. Carriage-makers, by heating the iron band, or tire, which surrounds the wheels of carriages, and putting it in its place while hot, bind these parts together with the greatest possible firmness.

42. Force of contraction.—The great force with which metals contract on cooling, was strikingly illustrated some years since in Paris. The two sides of a large building in that city, having been pressed out by the weight of its contents and the roof, M. Molard proposed to remedy the evil, by making several holes in the two walls, opposite to each other, through which strong iron bars should be introduced, so as to cross the inside of the building, from one wall to the other. On the projecting ends of the bars, on the outside of the building, were screwed strong plates of iron. The bars were then heated, by which their ends were made to project further beyond the walls, thus permitting the plates to be advanced, until they again touched the walls, which might be an inch, or more. The bars then, on cooling, contracted, and drew the walls as much nearer each other as the bars expanded in heating. There were two sets of these bars, so that, while one set was contracting and drawing the wall to its place, the other set was heating, and preparing to retain what was thus gained. In this manner, a force

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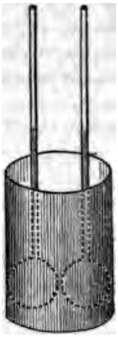
What relation is there between the expansion of metals and their fusibilities? What is the use of the pyrometer? Explain the construction of Daniel's pyrometer. In what mechanical arts is the expansion of the metals, by heat, turned to advantage? In what manner were the walls of a building in Paris drawn toward each other by means of heat?

was exerted, which the power of man could scarcely have applied by any other means, and by which the walls of an immense building were made to resume their perpendicular position.

43. EXPANSION OF LIQUIDS by heat, may be strikingly shown by means of a hollow glass ball, with a long small tube attached to it. When the ball, and a part of the neck, are filled with a liquid, and heat applied to the ball, the liquid expands, and continues to rise up the tube with considerable rapidity, until the liquid boils, when it will be thrown out with great force by the steam.

The different expansibilities of different fluids by the same increase of heat may be shown by two such vessels as that just described.

FIG. 10.



Expansion of Fluids.

On the tube of each, fix a mark at the same height, and fill one up to the mark with alcohol, and the other with water. Then plunge the bulbs of both into the same vessel of boiling hot water, thus making the heat applied to each exactly equal. Both the fluids will expand, and rise up the tubes, but the alcohol will be found to rise about twice as high as the water.

44. EXPANSION OF THE GASES.—It has already been remarked that the ratio of expansion in all aeriform fluids, is equal, with equal increments of heat.

If, therefore, the ratio of expansion for one gas, as for instance, oxygen, be known, then the ratio for all the other gases, as well as that for the common air, which we breathe, will be indicated.

From the experiments of several philosophers, it is proved, that this rate of expansion is equal to the $\frac{1}{480}$th part of the volume which the gas occupied, for every degree of Fahrenheit's scale, at 32 degrees and upward. This calculation is made from the experiments of Gay Lussac, who found that 100 parts, or volumes of air, at 32 degrees, expanded to 1375 parts, when heated to 212 degrees. The increase of bulk for 180 degrees,

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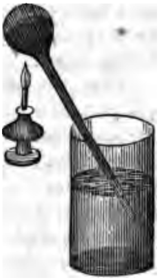
In what manner is the expansion of a fluid most strikingly shown? How are the different expansibilities of different fluids shown? Explain Fig. 10. How much more expansible is alcohol than water? What is the ratio of expansion in aeriform bodies? What is the difference in the bulk of 100 parts of air at the freezing and boiling points of water?

that is, from the freezing to the boiling point, is therefore 37½, which, by calculation, will be found nearly $\frac{1}{480}$th part for each degree.

The expansion of air by heat may readily be shown by blowing up a bladder, and securing the mouth by a string, so that none can escape, and then holding it toward the fire. As the air becomes rarefied by the heat, the bladder will become more and more tense, until it bursts with an explosive report.

A more elegant experiment is, to take a glass tube, terminated by a bulb, and put in so much water as to about half fill the tube, and then, having immersed it in a vessel of water, as represented in Fig. 11, apply the heat of a lamp to the bulb. As the heat rarefies the air in the bulb, the water will be forced down the tube, but will slowly rise again to its former place, by the pressure of the atmosphere on the fluid, when the heat is removed, and the air in the ball allowed to contract.

FIG. 11.



Rarefied Air.

RADIATION OF HEAT.

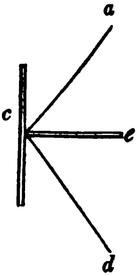
45. When we approach a heated body we become sensible that it emits caloric without touching it, and if a thermometer be carried near, this will indicate an increase of temperature. The caloric thus flowing from a heated body, is called *radiant caloric*, because it *radiates*, or is thrown off in all directions, like the rays of light from a radiant point. If the hand be held *under* the heated body, a sensation of warmth will still be perceived, which proves that this effect is produced without the intervention of a stream of heated air, which is felt only above the hot body, and never below it. Neither is this effect produced by the gradual conduction of the caloric by the air, for the heat from a hot ball may be felt in the open air, at a distance from it, and in the direction contrary to that of the wind. It is found also, that caloric radiates equally well through all the gases, and better through a vacuum than any medium; and hence we may infer that no medium at all is necessary for the passage of radiant caloric.

What simple experiments show the expansion of air by heat? Explain Fig. 11. What is meant by radiant heat? How is it proved that radiant heat is not conducted by the air?

When radiant caloric falls upon a solid or liquid, its rays are either reflected from it, and thus receive a new direction, or they lose their radiant form entirely by absorption into the body. Thus, a substance highly polished will throw the heat back toward the radiating body, and remain cold itself; while another substance, with a rough surface, will become warm at the same distance, because it absorbs, but does not reflect the heat.

46. ANGLES OF INCIDENCE AND REFLECTION.—Radiant heat and light follow exactly the same laws in their passage to and from polished surfaces, the angles of incidence and reflection being equal.

FIG. 12.

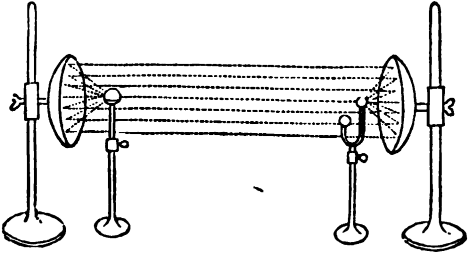


Radiation.

Thus, the ray *a*, *c*, Fig. 12, is the ray of incidence, and *c d* is the ray of reflection. The angles which *a c* make with the perpendicular line *e c*, and the plane of the mirror, are exactly equal to those made by *c*, *d*, with the same perpendicular and plane surface. (*See Optics in Natural Philosophy.*) Hence, with a concave mirror, the rays of heat, like those of light, may be concentrated, or collected to a focus, and by means of two such mirrors, very interesting experiments may be made, illustrating the laws of radiant heat in several respects.

47. CONCAVE MIRRORS.—Provide a pair of concave metallic mirrors, about ten or twelve inches in diameter, and two in concavity. They may be made of common

FIG. 13.



Radiation of Heat.

How is it shown that no medium at all is necessary to convey radiant caloric?

tinned iron, or of brass, which is better, but much more expensive.

These mirrors may be supported by stands made of wood, on which they slide up and down, and are fixed by thumb-screws, as represented in Fig. 13. Place the mirrors at the same height on a bench or table, exactly facing each other, and from ten to twenty feet apart, as they are less or more perfect, and place a screen of paper, or other substance, between them. Then, in the focus of one mirror, place a cannon ball, heated a little below redness, and in the other focus place a thermometer. When every thing is thus prepared, remove the screen, and the thermometer will instantly begin to rise, and will finally indicate a degree of temperature depending on the size and perfection of the mirrors, their distance apart, and the heat of the ball. The focus of a twelve-inch mirror, of the ordinary shape, is about four and a half inches distant from the center of concavity.

By placing the mirrors near each other, and using a red hot ball, a much more striking experiment may be made, for on removing the screen, powder will flash in the focus, as if by magic, since the eye can not detect the cause on which its inflammation depends.

The dotted lines in the drawing, Fig. 13, show the course of the rays of heat from the hot ball to the thermometer. The ball being placed in the focus of the mirror, the caloric radiates to all parts of its surface, and being reflected under the same angles at which it falls, the rays are thrown into parallel lines, and thus become incident rays to the second mirror. By the same law of incidence and reflection, the second mirror conveys the rays to a focus at the same distance before it that the hot ball is placed before the first mirror, because their focal distances are just equal. The heat of the ball is therefore concentrated on the bulb of the thermometer, which is placed in the focus of this mirror. If a burning lamp be placed in the focus of the first mirror, and a piece of paper, or the hand, in the focus of the second, there will be seen a bright, luminous spot on the paper, or hand, showing that light follows the same laws of reflection that heat does.

There is, however, a remarkable difference between the sub-

Does heat radiate through solid bodies? Explain Fig. 12, and show which is the ray of incidence, and which that of reflection. Explain Fig. 13; show the direction of the rays of heat from the heated ball to the mirrors, and from the mirror to the thermometer. How is it shown by the mirror that heat and light follow the same laws of reflection?

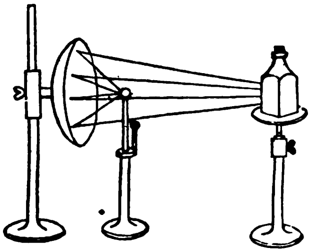
stances of which mirrors are commonly made, with respect to their power of reflecting heat and light. A concave glass mirror, covered in the usual manner with amalgam, when placed before a red hot cannon ball, will reflect the light, but not the heat, the mirror itself absorbing the radiant caloric, and soon growing warm. But a well polished metallic mirror reflects both the heat and light, and although held so near an ignited body, as, were it combustible, to be inflamed, it still remains cold. For the same reason, andirons, which are kept highly polished, will remain cold, though near a winter's fire. Any one who has undertaken to boil water in a silver cup, before the fire, will be convinced of the power of a bright metallic surface to resist the penetration of caloric.

48. Rate of cooling.—The nature, or colors of the surfaces of bodies, have also an important influence over their power of radiating caloric.

When other circumstances are equal, the rate at which bodies cool appears to be in an inverse ratio to the polish, or brightness of their surfaces. Thus, the surfaces of bodies are found to radiate heat more rapidly when they are rough than when smooth, and most rapidly when their surfaces are both rough and dark colored.

Mr. Leslie covered one side of a cubical tin vessel with lamp-black; another side with writing paper; a third with glass, and left the fourth uncovered.

FIG. 14.



Effects of Surface.

The vessel was then filled with hot water, and placed before a concave mirror, in the focus of which was placed an air thermometer, as represented by Fig. 14. On turning the black side toward the reflector, the fluid in the thermometer indicated a rise of temperature equal to 100 degrees; the papered side being turned toward the reflector, the thermometer sunk to 98 degrees; the glass side indicated 90

What is the difference between a mirror of glass, and one of metal, in their powers to reflect heat and light? Why do polished andirons remain cold when near the fire? Why is it difficult to boil water in a bright metallic vessel? What effect does the nature, or color of a surface, have on its radiating power?

degrees, and the metallic side only 12 degrees. The radiating power of these surfaces, therefore, are respectively to each other, as the numbers 100, 98, 90, and 12.

49. APPLICATION OF RADIATING POWERS.—Various practical uses may be made of this principle in the common concerns of life.

A close stove, intended to warm a room by radiating its heat to the objects surrounding it, should be dark colored, with a rough surface; while one intended to warm with hot air passing through it, should have a bright, metallic surface. A dark, rough stove pipe, passing through a room, might render it comfortably warm; while a polished tin pipe, of the same length and dimensions, would hardly change its temperature perceptibly. For the same reason, a highly polished metallic coffee-pot will keep its contents hot, while the contents of one made of dark earthenware would become nearly cold.

TRANSMISSION OF HEAT.

50. Rays of heat, in passing through air, are no more obstructed than those of light; but in passing other transparent media, heat is obstructed in various degrees, depending on some unknown property of the substance. It is well known that the rays of the sun, consisting of light and heat, may be so concentrated, by means of a parabolic mirror, as to fuse a metal, or inflame a combustible; and if a transparent body, as a plate of glass, be held between the sun and the mirror, or between it and the combustible, the effect will be but little, if at all, diminished.

51. Now if the same experiment be made with a common fire, or a number of lamps, though the heat and light are concentrated as before, yet if the glass plate be interposed, the heating effect, instead of remaining undiminished, as in the experiment with the sun, is reduced almost to nothing, while the spot of light remains as bright as before. Thus, the rays of heat, coming from the sun, pass through glass without difficulty, while the same substance almost entirely intercepts those made by art.

52. It is not, however, to be understood that glass is abso-

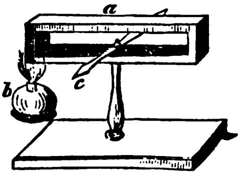
Describe Fig. 14, and explain how the different surfaces affect the thermometer. What practical uses may be made on the principles established by Mr. Leslie's experiment? Why does a bright coffee-pot keep its contents warm longer than one that is tarnished? What is said of the passage of the sun's heat through glass? What effect does a plate of glass have on the passage of culinary heat? Does glass entirely intercept the rays of artificial heat?

lutely impermeable to artificial radiant heat, for it has been found that the intense ignition of charcoal by voltaic action, produces an effect on the air thermometer when passed through a glass lens, and also that thin plates of the same substance will transmit indications of the heat of a powerful gas-burner.

53. Transmission of heat by different substances.—On this subject, M. Melloni, a French chemist, has made a series of curious and important experiments. These were made by means of the *thermo-multiplier*, an instrument much more sensible to small degrees of heat than the air thermometer. This instrument is constructed on the principle of *thermo-electricity*, of which the following is a description: first informing the student, that when two bars of different metals are connected together at each end, if one of the joints is heated more than the other, a current of electricity is immediately produced.

54. Thermo-electrical piles.—Now if a magnetic needle be exposed to the influence of the above described electrical current, it will be moved, or deflected out of its true position, even though only a single pair of bars be employed; and by using a series of such bars, and heating their alternate ends, the intensity of the electrical influence may be increased to any desirable extent. Such an instrument is called a *thermo-electric* pile. That used by M. Melloni in his experiments consisted of fifty-five bars of antimony, and as many of bismuth, laid side by side, with their alternate ends soldered together. Fig. 15 represents this thermometer; *a*, the metallic bars; *b*, a lamp heating one end of the pile, by which the electricity is developed, and the magnetic needle, *c*, is moved. The lamp being removed, and the end of the pile blackened, in order to promote the absorption of the rays of heat, the substances, whose powers of transmission were to be examined, having been cut into thin plates, were placed before the end of the pile. A screen, having an aperture equal to the face of the pile, was placed between the source of heat, and the plate to be tried,

FIG. 15.



Thermo Pile.

What is meant by thermo-electricity? What effect does the thermo-electrical current have on the magnetic needle? How is the thermo-electric pile constructed? In what manner is the pile employed?

while a second screen intercepted the rays of heat until the instant of trial.

55. By such means, M. Melloni obtained very curious, and often very unexpected results; and, among others, that bodies which transmit light most freely, often almost entirely intercept the rays of heat, while other transparent bodies are as permeable to heat as to light.

56. Bodies which allow the ready passage of heat, are called *transcalent*, or *diathermanous*, while those which intercept its rays are called *intranscalent*, or *adiathermanous*. Among all substances, rock salt is most highly transcalent, admitting the rays of heat to pass through it with very little interruption; while alum and glass, though fully as pervious to light as the salt, almost entirely intercept the calorific rays. On the contrary, some substances, though nearly opaque, with respect to light, admit the passage of heat with considerable facility, such as brown rock crystal, which was found nearly as transcalent as the most colorless specimens of the same material.

57. Bodies absolutely opaque, as wood, metals, and black marble, intercepted the rays of heat completely, although it was found that the faculty of transmission was possessed to a certain degree by nearly opaque substances, as thick plates of brown quartz, black mica, and black glass.

SPECIFIC CALORIC.

58. Equal weights of the same substance, at the same temperature, contain equal quantities of caloric; but equal weights of different substances, at the same temperature, contain unequal quantities of caloric. The quantity peculiar to each body, or substance, is called *specific caloric*. When one body of the same weight is found to contain more caloric than another, that containing the most is said to possess the greatest *capacity for caloric*.

59. When equal quantities of the same fluid, at different temperatures, are mingled together, the resulting temperature is a medium between these temperatures. Thus, if a quart of water at 100 degrees, be mixed with another quart of water at

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What singular results were obtained by means of this pile? What are transcalent bodies? What are intranscalent bodies? What difference is there between the transcalence of rock salt and alum? What is said of glass as a transcalent body? What substances are mentioned, which transmit heat without light? Do substances entirely opaque transmit heat? What is meant by specific caloric? What is meant by capacity for caloric? Suppose equal quantities of the same fluid, at different temperatures, are mixed, what will be the resulting temperature?

40 degrees, the temperature of the mixture will be 70 degrees. The same result will occur when any other liquid is mixed in equal proportions, but at different temperatures, as oil, alcohol, or mercury. But when equal quantities of different fluids are mingled together at different temperatures, the resulting temperature is not a medium, but is either above or below it.

60. CAPACITIES OF QUICKSILVER AND WATER.—We should expect, without experiment, that quicksilver would possess a greater capacity for caloric than the same bulk of water, and, therefore, that when equal quantities of these two fluids, at different temperatures, are mixed, the resulting temperature would be above the arithmetical mean. But in this we are disappointed; for if we mix a quart of water at 40 degrees, with a quart of quicksilver at 100 degrees, the temperature of the mixture will not be 70 degrees, as in the experiment with the water alone, but only 60 degrees. This proves that a quart of quicksilver, although it weighs about fourteen times as much as a quart of water, still contains less caloric, and, therefore, that water has a greater capacity for caloric than quicksilver; for, in the first experiment, a quart of water at 100 degrees, raised the temperature of another quart at 40 degrees, to 70 degrees; but here, a quart of quicksilver at 100 degrees, raises the heat of the same bulk of water to only 60 degrees. The quicksilver, then, loses 40 degrees, which nevertheless raises the temperature of the water only 20 degrees.

61. The relative capacities of water and quicksilver for heat, may be shown by mixing equal weights of the two fluids at different temperatures, and then ascertaining how much the resulting temperature differs from the arithmetical mean.

Mix a pound of water at 100 degrees with the same weight of mercury at 40 degrees, and the heat of the mixture will be 98 degrees; that is, 28 degrees above the arithmetical mean, because when equal weights of water were mixed at these temperatures, the resulting temperature was only 70 degrees; but here it is 98. The water, then, has lost only 2 degrees, while the same weight of mercury has gained 58 degrees, for the temperature of the mercury before the mixture was only 40 degrees, while that of the water was 100 degrees. The capacity

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When fluids of different kinds are mixed under the same circumstances, will the resulting temperature be a medium? Which fluid has the greatest capacity for caloric, water or quicksilver? How is this shown? If a pound of mercury at 40 degrees be mixed with a pound of water at 100 degrees, what will be the resulting temperature?

of water for heat, is therefore to the capacity of mercury for the same, in the proportion of 58 to 2, or as 29 to 1.

62. It appears from a great variety of experiments made by different philosophers on this curious subject, that whatever may be the cause of the different capacities of bodies for heat, the effect is greatly influenced by the state of density in which such bodies exist, and that in general their capacities increase, in a ratio to the decrease of their specific gravities. In the above experiment, the capacity of water is to mercury as 29 to 1, while their specific gravities are as 1 to 14.

63. Capacity of the gases.—Various methods have been employed by philosophers to ascertain the capacities of the several gases for heat.

64. To determine and compare the relative capacities of these bodies in this respect, Gay Lussac contrived an apparatus, by means of which, a hot current of one gas met a cold current of another gas, in the center of a small reservoir, containing a thermometer. A thermometer was also placed in the current of each gas before they met. Thus, by knowing their temperatures before their mixture, and afterward, it was easy to infer their respective capacities for caloric.

65. Bernard, in order to determine the specific caloric of elastic fluids, caused them to pass through a pipe inclosed in a larger pipe, the latter being constantly filled with steam. In this manner he was enabled to know precisely the temperature of the gas under experiment, and also to raise the temperature of each to the same degree. Having thus determined its temperature, the gas was then made to pass into a spiral tube immersed in cold water, and the specific caloric of each gas was inferred by the quantity of heat it imparted to the water. By these and similar experiments, it has been ascertained that the aeriform fluids differ greatly in the quantities of their specific caloric,—thus, the capacity of hydrogen for caloric is more than twelve times greater than the capacity of an equal bulk of atmospheric air, though the air weighs about thirteen times as much as the hydrogen. It is also ascertained that out of nine gases on which experiments were made, none except hydrogen has a capacity for heat equal to that of water, but that they all

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What are the proportionate capacities of mercury and water for heat? In general, do the capacities of bodies for heat increase, or decrease, with their densities? By what method did Gay Lussac determine the capacities of the gases for caloric? By what method did Bernard determine the capacities of the gases for caloric? What gas has the greatest capacity for heat? In general, what class of bodies have the greatest, and what the least capacity for heat?

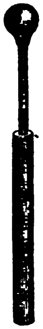
have greater capacities than any of the metals. Hydrogen, the lightest of all bodies, has the greatest capacity for heat, while the metals, the most ponderous of all bodies, have the least.

66. The same substance by having its bulk enlarged, and consequently its density decreased, acquires an increased capacity for caloric. Thus water, when thrown on the bulb of a thermometer, sinks the mercury, because, in assuming the form of vapor, its capacity for caloric is increased, and it consequently absorbs and carries away the heat from the mercury. Some philosophers have accounted, in part, for the intense cold in the upper regions of the atmosphere, on the supposition of the increased capacity of the air for heat as the pressure of the incumbent atmosphere is removed.

67. Ignition by pressure.—On the contrary, we know, that by increasing the density of air, its capacity for caloric is diminished, and that under certain circumstances sufficient heat may be set free in this manner to produce ignition.

This effect may be produced by the little instrument represented by Fig. 16. It consists of a metallic tube, ten or twelve inches long, the bore of which is less than half an inch in diameter. To this is fitted a rod and piston, moving air-tight; the lower end of the piston being excavated to receive a little tinder. When the piston is suddenly forced down, nearly to the bottom of the tube, the condensation of the air it contains, evolves so much heat, as to set fire to the tinder in the end of the piston, and in this way a fire may conveniently be kindled.

FIG. 16.



Fire Gun.

68. Table of specific caloric.—By the following table it will be seen that there are extraordinary differences in the capacities of different substances for containing heat. These results were obtained by the most accurate modes of experiment, by the French philosopher Regnault.

Substances.	Specific heat in equal weights.	Substances.	Specific heat in equal weights.
Water, . . .	1000	Wood charcoal,	241
Ice, ...	513	Sulphur, . . .	203
Oil of turpentine,	416	Glass, ...	198

If a body has its bulk enlarged, is its capacity for heat increased or diminished thereby? How has the intense cold of the upper regions been accounted for on this principle?

Substances.	Specific heat in equal weights.	Substances.	Specific heat in equal weights.
Diamond, . .	147	Tin, ...	56.23
Iron, ...	113.79	Iodine, ...	54.12
Nickel, . . .	108.63	Antimony, ...	50.77
Cobalt, . . .	106.96	Gold, ...	32.44
Zinc, ...	95.55	Platinum, ...	32.43
Copper, . . .	95.15	Mercury, ...	33.32
Arsenic, . . .	81.40	Lead, ...	31.40
Silver, ...	57.01	Bismuth, ...	30.84

OBSERVATION.—In chemistry, nothing must be left to conjecture, all must be tried by experiment, and the result is often what was least expected. In the present case, without experiment, who could have imagined that the capacity for heat is greater in water and ice than in platinum, gold, and silver; and yet we find that water has more than twenty times the capacity of the most dense metals.

VAPORIZATION.

69. By *vaporization* or *evaporation* is meant the conversion of a liquid, or solid into an aeriform body. This, with respect to most solids is performed by heat more or less intense, according to the nature of the substance, and it is even supposed that with sufficient degrees of heat, all substances would become elastic fluids. But many substances, as water and alcohol, and even some solids, as camphor and ice, evaporate by mere exposure to the air. In general, however, when a solid is converted into vapor by heat, the process is called *sublimation*, thus sulphur and mercury, and some other solids are purified by sublimation, or dry distillation.

We have already spoken of evaporation. chiefly as induced by ebullition, but the subject has several other bearings which it will be well to illustrate and explain.

70. MAXIMUM DENSITY.—At a certain degree of heat there exists for the vapor of different substances a state of density which it can not pass without losing its gaseous condition, and becoming a liquid. This point is called its state of *maximum density*. When a volatile liquid is introduced in sufficient quantity into a vacuum, this condition is already reached, and then

How is it proved that the air has less capacity for heat when condensed than otherwise? What is the difference between evaporation and sublimation? What is meant by the maximum density of a gas?

evaporation ceases; and any attempt to increase the density of this vapor by compressing it in a smaller space, will be attended by its liquefaction. Thus, if a little ether be introduced into a barometer tube, and the tube be slowly sunk into a deep cistern of mercury, it will be found that the height of the mercury in the glass will remain unaltered, until the upper extremity of the barometer approaches the surface of the metal in the reservoir. It will be observed also, that as the tube sinks, the little stratum of liquid ether increases in thickness, but no increase of elastic force occurs in the vapor above it, and, consequently, no increase of density; for tension and density in elastic bodies, are always directly proportionate to each other.

71. The point of maximum density of a vapor is dependent upon the temperature; it increases rapidly as the temperature rises. Thus, taking the specific density of atmospheric air at 212 degrees to be 1000, then that of aqueous vapor in its greatest state of compression at different temperatures will be as follows :—

Temperature.	Specific gravity.	Weight of 100 cubic inches.
32 degrees.	5.590	.136 grains.
50 "	10.293	.247 "
60 "	14.108	.338 "
100 "	46.500	1.113 "
150 "	170.293	4.076 "
212 "	625.000	14.962 "

Thus pressure, by increasing the density, may cause an elastic fluid to assume the liquid form; and the same effect, in many instances, is produced by cold, inasmuch as loss of heat depresses the point of maximum density. (*See Liquefaction of the Gases.*)

THERMOMETER.

72. The *thermometer* is an instrument founded on the principle that the expansion of matter is proportional to the augmentation of temperature, and is designed to measure the variations of heat and cold.

The first attempt to measure such variations on this principle was made by Sanctorius, an Italian physician, in the seventeenth

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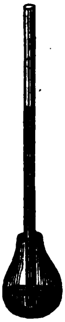
On what principle is the thermometer constructed? Who first constructed thermometers? What fluid was first employed to indicate the variations of temperature?

century. He employed a glass tube, blown into a ball at one extremity, and open at the other. After expelling a small part of the air by heating the ball, the open end was plunged into a vessel of colored fluid, and as the air in the ball cooled, the fluid ascended up the tube. Any variation of temperature by expanding, or contracting the air in the ball, would then cause the liquid in the tube to rise or fall; thus formiug an imperfect air thermometer.

FIG. 17.



Air Thermometer.

73. A better construction for an air thermometer is represented at Fig. 17. It consists of a thin glass bottle, containing a small quantity of a colored liquid, and stopped closely by a cork. Through the cork is passed a broken thermometer tube, open at both ends. This tube descends nearly to the bottom of the bottle, and dips into the fluid. There is, therefore, a quantity of air above the fluid which can not escape, and when this expands by the application of heat, the fluid is forced up the tube. Thus the height of the fluid will indicate the expansion of the air, and consequently, the degree of heat to which the instrument is exposed.

There are, however, two objections to the employment of air for this purpose. Its expansions and contractions are so great, even by small changes of temperature, that a tube several feet in length would be required to measure them; and as air suffers condensation by pressure, the variation of the barometer would affect its height, at the same temperature.

74. DIFFERENTIAL THERMOMETER.—For the above reasons, the air thermometer, for common purposes, is both inconvenient and inaccurate, and therefore has long since been laid aside. There is, however, a modification of this instrument, invented by Mr. Leslie, and called the *differential* thermometer, which for certain purposes is a very elegant and useful instrument.

A drawing of this instrument is represented by Fig. 18, and it is designed, as its name imports, to show the difference of temperature between two places at short distances from each other. It consists of a glass tube terminated at each end by a bulb, and bent as shown in the figure. The tube is partly filled with some colored fluid, as sulphuric acid, tinged with carmine,

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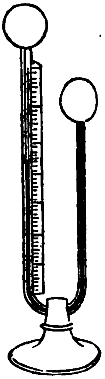
Describe the construction af an air thermometer. What are the objections to the air thermometer? How is the differential thermometer constructed, and for what purposes is it useful.

FIG. 18.



Lesties' Thermometer.

or alcohol, colored by cochineal, the bulbs and other parts of the tube being filled with air.

It will be obvious, from the construction of this instrument, that it can not indicate the temperature of the atmosphere, since an equal expansion of the air in both bulbs would press equally on the fluid in both legs of the tube, and consequently it would rise in neither. But if one bulb is exposed to a higher temperature than the other, then the expansion of the air in this, will be greater than in the other, and consequently the fluid will rise toward the bulb where the air is least expanded.

75. Use.—The use of this thermometer, then, consists in showing the *difference* of temperature to which the bulbs are exposed, as in experiments on the radiation of heat, already described. The scale affixed to one of the legs, shows the rise in degrees, and is divided into 100 parts. The legs are six inches long, and the bulbs an inch or a little more in diameter. The stand may be of glass or wood. Some of these instruments are so delicate as to be affected by the approach of the hand.

Air, being inapplicable to the construction of thermometers for the purpose of measuring the absolute temperature of places or things, for the reasons already noticed, solid bodies are equally so from a contrary defect; their expansion by heat being so small as not to be appreciated without the adaptation of complicated machinery. A perfect substance for this purpose would be a fluid, which would expand uniformly with equal increments of heat, and which would neither freeze nor boil at any temperature to which it might be exposed. Mercury approaches nearer to these conditions than any other substance, and therefore this is the fluid now almost universally employed.

76. Construction of the thermometer.—The blowing of the best thermometer tubes requires much experience and skill in the workmen, and is performed only by particular artists. This is the most difficult part of its construction. The mercury is introduced by heating the bulb, and thus rarefying the air

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Why will not the differential thermometer indicate the temperature of the atmosphere? Why are not solid bodies proper for the construction of thermometers?

within it, and then dipping the open end of the tube into a vessel of the fluid. As the air contracts within by cooling, the pressure of the external atmosphere forces the mercury to enter the tube to supply its place. When the bulb is nearly filled in this way, the mercury is boiled to expel the air.

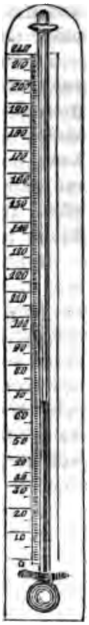
Having filled about one-third of the tube, the open end is sealed hermetically, that is, by melting the glass. This is done while the mercury in the bulb is heated nearly to its boiling point, so as to exclude all the air.

Having sealed the end of the tube, the next step in the construction of the thermometer, is its graduation. This is done by ascertaining two fixed and invariable points on the tube, which are the same in every thermometer, and then by making a scale of equal divisions between these two points. These are the freezing and boiling points.

The freezing point is found by immersing the bulb of the thermometer in melting snow or ice, for it has been ascertained, that the temperature of water flowing from melting snow or ice, is every where the same, whatever may be the heat of the atmosphere where the experiment is made. The boiling point is slightly affected by the pressure of the atmosphere; but the thermometer will be sufficiently accurate for all ordinary purposes, when this point is ascertained by immersing the bulb in pure boiling water, open to the air, and on the level of the sea, during pleasant weather. (*See Barometer, in Natural Philosophy.*)

The freezing and boiling points are marked with a diamond or file, on the tube; and on the scale to be afterward affixed, the freezing point is marked 32, and the boiling point, 212. The interval between these two points is then accurately divided in 180 equal parts. This is the division of Fahrenheit's scale, the thermometer generally employed in this country, and is the only scale referred to in this work.

FIG. 19.



Thermometer.

What would be a perfect substance for the construction of thermometers? What is the most perfect fluid in our possession for this purpose? How are thermometer tubes filled? How is the freezing point of the thermometer ascertained? How is the boiling point ascertained?

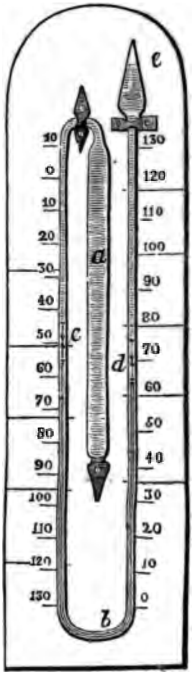
The commencement of this scale is 32 degrees below the freezing point, and is called *zero*, being marked with the cipher 0, to signify the total absence of heat. This degree of cold, it is supposed, Fahrenheit obtained by mixing snow and common salt, and it was probably the greatest degree of cold known in his time, though at the present day certain mixtures produce much greater, and at a future period, the progress of science may show the means of abstracting heat, so as to solidify even the air we breathe. The absolute zero must therefore be considered an imaginary point.

Besides the zero and the freezing and boiling points, marked on Fahrenheit's scale, Fig. 19, there are also noted the temperature of the blood, and the heat of summer, and sometimes other points, as fever heat, &c.

77. **SELF-REGISTERING THERMOMETER.**—Several ways have been invented to make thermometers mark their own temperatures, in such a manner as to leave permanent indications of the highest and lowest points of the mercury, after the temperature has changed. Thus, in attempting to find the temperature of the deep ocean by the common thermometer, it is easy to see that the object would be defeated by the change of the temperature as the instrument is drawn toward the surface. If, however, a mark could be left at the point where the mercury stood when it was at the greatest depth, then the object in question would be attained, and this is what the self-registering thermometer performs.

78. **SIX'S THERMOMETER.**—The best instrument of this kind is known by the name of Six's *self-registering* thermometer, Fig. 20. It consists of a single glass tube, twice bent, and having a large, elongated, cylindrical bulb, *a*, filled with alcohol, which reaches down

FIG. 20.



Six's Thermometer.

Describe the construction and use of Six's thermometer.

the small tube to *c*, where it rests on a column of mercury, which extends down to *b* and up to *d*, above which it is filled with alcohol, so that the lower portions of the tube are filled with mercury, and the upper with alcohol. On each side, and in contact with the mercury, is placed a little iron index, *c* and *d*, to which are fixed by cement a hair, which pressing against the side of the tube, fixes the index in any place unless forcibly moved by the expansion of the mercury. These iron indexes are placed in contact with the mercury, by means of a magnet carried along the outside of the tube. They, therefore, float on the mercury, and are covered by the alcohol. Now, when the alcohol in the large bulb, *a*, expands, it drives the mercury up the opposite tube, say to *d*, where, on its contraction, the index is left. On the contrary, if the alcohol contracts by cold, the opposite index, *c*, rises, and, in like manner, is left at the point of the greatest contraction, if the alcohol again expands; so that, by this curious instrument, the highest and lowest degrees of heat are indicated to which it has been at any time exposed, and which may be known, by inspection, days or weeks afterward.

The tube is expanded at *e*, where it is filled with its contents, and then sealed by melting the glass.

LIQUEFACTION OF THE GASES.

79. The experiments of Mr. Faraday and others, on the liquefaction of the gases, have resulted in the opinion that these aeriform bodies are nothing more than the vapors of extremely volatile liquids. Most of these liquids, if they are such, are naturally so volatile, that their boiling points, under the ordinary pressure of the atmosphere, are below the temperature of the coldest regions of the globe, and hence they are always found in the gaseous state. But by subjecting several of them to great pressure, their gaseous condition is so far counteracted as to make them form liquids, and in one instance, even a solid. Even when so compressed, a very small additional heat will make them boil, and the instant the pressure is removed, they again assume the elastic form, and some of them, with such violence as to cause an explosion of more or less intensity. This sudden change of a solid, or liquid, into the elastic state,

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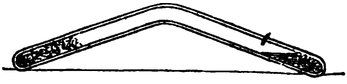
What opinion exists about the form of the gases? What is the reason that the gases do not retain their liquid states? In what manner may the gases be made to assume the liquid form?

in consequence of changing the heat from a sensible to a latent condition, produces a remarkable degree of cold.

80. PROCESS FOR CONDENSING THE GASES.—The method of condensing the gases consists in exposing them to the pressure of their own elasticity, or their own atmospheres. The process is exceedingly simple, and may be performed by any one, though without care and experience, it may be attended with much danger to the experimenter.

FIG. 21.



Condensation of Gas.

The materials to form the gas are put into a strong glass tube, Fig. 21, bent as in the figure, after which the orifice is hermetically sealed, or closed by means of a metallic cap with some strong cement. In most instances, it is necessary that the materials should be kept apart, until the tube is closed, after which, by a change of position, they are brought to act on each other. Thus, for carbonic acid gas, some dilute sulphuric acid is poured into the tube, and at the other end is placed some pieces of chalk or marble, and after the orifice is closed, by changing the position of the tube, they are brought together, when the gas is instantly evolved.

81. The amount of pressure required to liquefy the different gases is quite variable. Thus, sulphuric acid gas requires only two atmospheres at 45 degrees; carbonic acid gas thirty-six atmospheres at 32 degrees, while nitrous oxide gas does not become liquid at a less pressure than fifty atmospheres.

Now, taking the pressure of the atmosphere to be equal to 15 pounds to the square inch, and the size of the tube on the inside equal to an inch square, then the force on the tube in which nitrous oxide becomes liquid, would be (provided the tube be eight inches long) equal to 6,000 pounds, for 15 lbs. $\times$ 50 atmospheres$=$750, which $\times$ by 8 inches long$=$6,000.

82. Carbonic acid is the only gas which has been reduced to the solid form. To prepare this, a very strong metallic apparatus is required, involving considerable expense, and perhaps not a little difficulty to those not in the practice of making chem-

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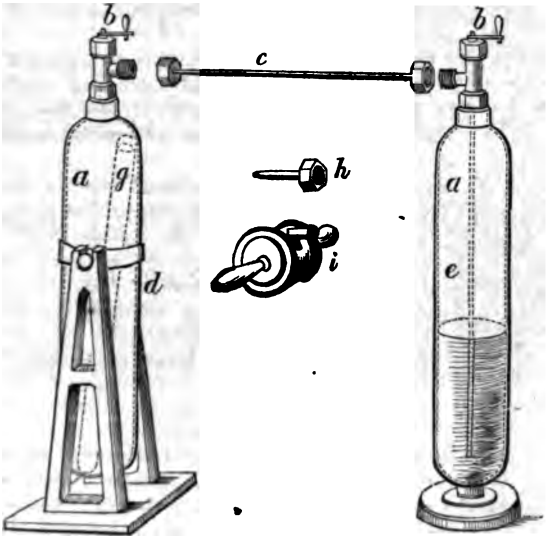
Describe the apparatus and process of condensing the gases. Do all the gases require the same amount of pressure for their liquefaction? What gas requires the least and what the greatest pressure for this purpose? What is the amount of pressure which nitrous oxide requires for its liquefaction? What phenomena does carbonic acid exhibit in the solid state? What numbers are marked on the scale at the freezing and boiling points? What is the number of degrees between these two points?

ical experiments. When prepared, if a small jet be permitted to escape by the turning of a stop-cock, the most intense action instantly follows, attended by such a degree of cold as actually to freeze the portion which has not made its escape from the vessel. When frozen, it has the appearance of ~~fine~~, moist snow, which being exposed to the air soon evaporates, but if covered with cotton, may be preserved in the solid state for hours.

In some instances heat is required in order to separate the gas from its combinations, after which the process of liquefaction is greatly facilitated by cold. This is produced by surrounding the vessel containing the gas with pounded ice, or snow, mixed with common salt.

83. **Apparatus of Thilorier for condensing the gases.** By the machinery represented by Fig. 22, and its uses which we shall try to make understood, large quantities of liquid and even solid carbonic acid, may be obtained.

FIG. 22.



Apparatus for Condensing the Gases.

What does zero signify? How far below the freezing point is the zero of Fahrenheit? Is the point of the absolute zero known?

It consists of two similar cylindrical vessels of wrought iron, half an inch thick, and holding about half a gallon, each being furnished with a stop-cock, which is closed by means of screws, turned by the handles *b*, *b*. The gas is evolved in the vessel *d*, which is suspended on a wooden frame, and in which is put the requisite quantity of bicarbonate of soda from which the gas is derived. In this is placed the copper tube *g*, containing an equivalent of sulphuric acid to saturate the soda; the cap being secured, the whole is inverted by turning the vessel in the frame, and the acid and soda being thus mixed, the gas in question is evolved in quantities proportionate to those of the materials; and there being no escape for the gas, an enormous pressure is produced, which requires great strength in the vessel to withstand.

After the gas is thus produced, the two vessels are connected by means of coupling screws and the tube *c*, and the liquefied gas flows from the generator to the receiver, *e*, where it is further condensed by freezing mixtures.

The charge for generating the gas consists of a pound and a half of the soda, dissolved in a quart of water, and a pound of sulphuric acid put into the copper tube. After two or three charges thus forced into the receiver, the pressure becomes sufficient to liquefy the gas.

From the stop-cock of the receiver a small tube, *e*, descends nearly to the bottom and dips into the liquid, so that on opening the former, it is the liquid, and not the gaseous acid which escapes. The nozzle, *h*, being fixed to the receiver, and the stream of liquid acid directed into a small tin box with wooden handles, *i*, surrounded with a freezing mixture, the carbonic fluid assumes the form and appearance of snow. Its temperature is about 148 degrees Fahrenheit below the freezing point.

COLD.

84. Cold is a negative condition, and depends on the absence, or privation of heat. Intense artificial cold may be produced by the rapid absorption of heat during the conversion of solids into liquids. Dr. Black long since discovered the principle, that when bodies pass from a denser to a rarer state, heat is absorbed and becomes latent in the body so transformed, and

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Describe the method of making large quantities of liquid carbonic acid. What is its appearance and temperature? What is cold? How may intense artificial cold be produced? When bodies pass from a denser to a rarer state, is heat or cold produced?

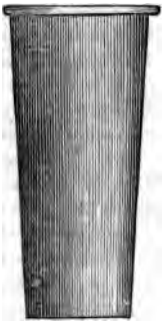
consequently cold is produced. And also that when bodies pass from a rarer to a denser state, their latent heat is evolved, and becomes sensible.

It is known to almost every one, that dissolving common salt in water, particularly if the salt is fine, will render the water so cold, even in summer, as to be painful to the hand. The salt, as it passes from the solid to the liquid state, absorbs caloric from the water, and thus the heat that was before sensible, becomes latent, and cold is produced.

85. Heat by condensation.—On the contrary, when a piece of lead, or iron, is beaten smartly with a hammer, it becomes hot, because the metal in consequence of the hammering, has its capacity for caloric reduced, and thus the heat which was before latent, now becomes sensible. For the same reason, when air is compressed forcibly in a tube, or as it is sometimes called, in a *fire-pump*, as already explained, the heat, which was before latent, becomes sensible, because the condensation lessens its capacity for caloric.

The principle on which all freezing mixtures act, is therefore the change of state which one or more of the articles employed undergo during the process, and this change consists in an enlarged capacity for caloric. The degree of cold will then depend on the quantity of caloric which passes from a free to a latent state, and this again will depend on the quantity of substance liquefied, and the rapidity of the liquefaction.

FIG. 23.



Ice Cream.

86. Salt and snow.—The substances most commonly employed for this purpose are those originally used by Fahrenheit, to produce the zero of his thermometric scale, viz.: common salt and snow, or pounded ice. For this purpose the salt should be fine, and the ice, which must always be used in summer, is to be reduced to small particles in a cold mortar.

87. The vessel to contain the substance to be frozen may be made of tin, and of the shape represented by Fig. 23. It is simply a tall vessel, holding a few pints, with a close

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How is the temperature of water generally known to be affected by dissolving common salt in it? How is this change of temperature accounted for? Why does a piece of iron become hot by hammering? How do you account for the heat evolved, where air is compressed? What is the principle on which freezing mixtures act?

cover, and a rim round the top, for the convenience of handling it. For common purposes, this may be set into any convenient wooden vessel, (having first introduced the substance to be frozen,) and then surrounded by the freezing mixture. The only care to be taken in this part of the process is, to see that the freezing mixture in the outside vessel reaches as high as the contents of the internal one. With two or three pounds of fine common salt, and double this weight of pounded ice, three or four pints of iced cream may be made in this way, during the warmest days of summer. The process requires two or three hours, and while it is going on, the vessel should be set in a cellar, or covered with a flannel cloth, as a bad conductor of the external heat.

88. When the thermometer is at 32 degrees, the cold generated by the above process sinks it down to zero. By this method, two solids are changed into liquids, and both during the change absorb caloric from the contents of the inner vessel. The salt melts the ice in consequence of the avidity with which it imbibes moisture, or by reason of its affinity to water, and the water in its turn dissolves the salt.

Other substances, having a stronger affinity (*see Affinity*) for water than common salt, will produce the same effects still more powerfully. Thus, muriate of lime (*see this article*) five parts, and ice four parts, will sink the thermometer from 32 degrees to 40 degrees below zero, that is, in the whole, 72 degrees. At this temperature, mercury freezes. A still more effective mixture is four parts of fused potash, and three parts of snow. This is said to sink the mercury from 32 degrees to 50 degrees below zero, that is, 82 degrees. In these experiments the thermometers are filled with alcohol, instead of mercury.

89. Freezing mixtures are also made of a solid and a fluid. One of the most effectual of this kind is composed of diluted sulphuric acid and snow, or pounded ice. This sinks the mercury from 32 degrees to 23 degrees below zero.

Though ice or snow is commonly employed for this purpose, still powerful frigioric effects may be produced without either, the absorption of caloric being caused by the rapid solution of

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On what circumstance will the degree of cold produced by freezing mixtures depend? What are the substances most commonly used as freezing mixtures? Explain Fig. 23, and show how it is to be used. How far below 32 degrees will a mixture of ice and common salt sink the thermometer? Why does the salt melt the ice? What substance sinks the thermometer from 32 to 40 degrees below zero? In these experiments, why is alcohol used to fill the thermometer, instead of mercury? What is said of sulphuric acid and snow, as a freezing mixture?

a salt in a fluid. One of the most common and cheap among these is a mixture of sulphate of soda, or Glauber's salt, and diluted sulphuric acid. This sinks the mercury from 50 degrees to 3 degrees above the freezing point, that is 47 degrees.

90.. In describing experiments of this kind, it should always be noted from what point the thermometer begins to descend, otherwise no judgment of the power of the freezing mixture can be formed. If, for instance, a mixture would cause the depression of the thermometer from and below any given point, then by repeating the process continually, we should be able to find the absolute zero. Thus, by means of muriate of lime and snow, the thermometer is made to sink 82 degrees, that is, from 32 degrees above, to 50 degrees below zero. Now, if the same cause would again produce the same effect, by its reapplication, the thermometer would sink to 132 degrees below zero, a degree of cold not to be obtained by such means. But an unlimited degree of cold can never be produced by the art of man; for it is found on experiment, that when the temperature produced by the freezing mixture is greatly below that of the air, the caloric is so rapidly communicated, as to prevent any effect by repeating the process. Mr. Walker, who made a great number of experiments on this subject, was never able to produce a greater degree of cold than that of 100 degrees below the zero of Fahrenheit.

91. TEMPERATURES.—The following facts and circumstances with respect to Temperatures are both interesting and important. They were measured by Fahrenheit's scale. The dash — indicates that the number is below zero.

—220	degrees.	Greatest artificial cold, (Natterer.)
—166	"	" " " (Faraday.)
—150	"	Liquid nitrous oxide freezes, (Faraday.)
—122	"	Liquid sulphureted hydrogen freezes, (Faraday.)
—105	"	Liquid sulphuric acid freezes, (Faraday.)
— 71	"	Liquid carbonic acid freezes, (Faraday.)
— 91	"	Greatest artificial cold, (Walker.)
— 56	"	Greatest natural cold, arctic regions, (Sabine.)
— 58	"	Estimated temperature of planetary space, (Fourier.)

What substances form a freezing mixture without the use of ice or snow? In making experiments with freezing mixtures, why is it necessary to state the degree from which the thermometer begins to fall? What is the reason that an unlimited degree of cold can not be produced by art? What is the greatest degree of cold ever produced?

— 70	degrees.	Greatest natural cold observed, (Capt. Back.)
— 47	"	Sulphuric ether freezes.
— 39	"	Mercury freezes.
— 30	"	Liquid cyanogen freezes, (Faraday.)
— 7	"	Equal parts of alcohol and water freeze.
20	"	Wine freezes.
32	"	Ice melts.
50.7	"	Mean temperature of London.
81.5	"	Mean temperature at the Equator.
98	"	Heat of the human blood.
117	"	Hot wind in Upper Egypt, (Bruckhardt.)
151	"	Wood spirit boils.
173	"	Alcohol boils.
212	"	Water boils at the level of the sea.
442	"	Tin melts.
594	"	Lead melts.
662	"	Mercury boils.
980	"	to 1000. Iron becomes red hot.
1141	"	Heat of a common fire, (Daniel.)
1869	"	Brass melts, "
2283	"	Silver melts, "
3479	"	Cast iron melts. "

92. OBSERVATIONS ABOUT COLD AND HEAT.—Our notions of the range of temperature acquire all their precision from the use of the thermometer. Cold and heat, in popular estimation, are both considered as substantial things. But cold is the mere absence of heat, as darkness is the absence of light. But in the open air, at least, the light is never entirely absent, nor is there any condition in which heat does not remain. Thus, ice, cold as it is, when compared with our sensations, is only 32 degrees, or at the freezing point of Fahrenheit, while, according to the above table, the thermometer may be cooled more than 180 degrees below this point. Compared with this temperature, therefore, ice, under common circumstances, contains more than 180 degrees of heat. But alcohol has so strong an affinity to heat, as to remain fluid under the greatest absence of it which art has been able to produce, this being among the few liquids which has not been frozen; and yet it, no doubt, has its freezing point, like other fluids, the only difficulty being to find this point, by abstracting its heat.

Does ice contain any heat? How many degrees of heat may ice contain? What is said about the freezing of alcohol?

SOURCES OF CALORIC.

93. The sources of caloric may be reduced to six, viz. The Sun, Combustion, Electricity, the bodies of living warm-blooded animals, Chemical action, and Mechanical action.

The SUN constantly radiates caloric to the earth, and is the great fountain of heat to us and to the whole solar system.

94. COMBUSTION.—This supplies the heat employed in the arts, and for culinary purposes. In this process the caloric is extricated from the oxygen of the atmosphere, as it unites with the burning body and supports its combustion. The light is supposed to be furnished by the burning body.

95. ELECTRICITY.—Whenever two bodies in opposite electrical states are made to approach each other, so as to produce a discharge through the air, or along a non-conductor, there appears a flash of light, attended by heat. By the action of galvanism, which is a modification of electricity, the most intense heat hitherto known has been produced.

When the electric fluid passes through a piece of metal, or other conductor, of sufficient size, no phenomena are produced; but in its passage through a non-conductor, or through a conductor which is too small to admit of a free passage, heat is produced. (*See Electricity, in Natural Philosophy.*)

96. VITAL ACTION.—The bodies of air-breathing animals are a continual source of heat. The numerous theories which have been invented to account for the cause of animal heat can not here be investigated. That it however depends on the oxygen of the atmosphere which we breathe, seems to be proved by the fact, that animal warmth can not for any length of time be sustained without it.

97. CHEMICAL ACTION.—Chemical action without combustion is capable of producing considerable degrees of heat. If water be thrown on unslacked quicklime, in small quantities at a time, its heat will be gradually augmented to nearly 1000 degrees, or so as to ignite wood. The heat in this experiment is accounted for, on the law already explained, that when bodies pass from a rarer to a denser state, caloric is evolved. The slaking lime absorbs the water, and retains it as a part of its substance, and thus a fluid is converted into a solid, with the evolution of much caloric.

What are the sources of caloric? What is the great fountain of heat? How is heat extricated by combustion? When does electricity produce heat? What is the cause of electrical heat? What is said of vital action, as a cause of heat? What is said of chemical action as the cause of heat?

If three parts of strong sulphuric acid and one of water be suddenly mixed together, a degree of heat considerably above that of boiling water will be produced. In this case the heat is also accounted for on the principle of condensation, for if the two fluids be measured before and after mixture, it will be found that their union has occasioned a loss of bulk, and probably also a loss of capacity for caloric.

The inflammation of spirit of turpentine by nitric acid is a case of intense chemical action, in which 1000 degrees of heat are evolved. About an ounce of the turpentine, with the same weight of nitric, mixed with a little sulphuric acid, are the proportions. The acid should be poured on the turpentine from a vessel tied to a rod several feet long, as the explosion sometimes throws the burning matter to a considerable distance.

98. Mechanical action.—This includes *percussion, friction, and condensation.*

Caloric is evolved by the *percussion* of hard bodies against each other. This is owing to the condensation of the body struck, in consequence of which its latent heat becomes sensible.

If a piece of soft iron be struck smartly several times with a hammer, on an anvil, it becomes hot, and even red hot, if the experiment be well conducted.

When a piece of steel and a flint are struck together, the condensation produces so much heat as to set fire to the small particles of steel which at the same time are struck off by the blow.

99. Friction.—Caloric is evolved, or produced by friction. The friction of machinery, when the motion is rapid, frequently causes so much heat as to set the wood on fire. The inhabitants of various nations obtain fire by rubbing pieces of dry wood together. The friction of carriage-wheels sometimes sets them on fire.

The principle on which caloric is produced by friction has not been demonstrated. It can not be referred to condensation, since the rubbing of two soft bodies together, such as the hand against the coat-sleeve, or the two hands against each other, cause heat.

Count Rumford, who made a laborious and varied course of experiments on this subject, was led to the conclusion that the

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How is the heat produced by throwing water on quicklime accounted for? When sulphuric acid and water are mixed, what is the cause of the heat produced? How may spirits of turpentine be inflamed by chemical action? What does mechanical action, as a source of heat, include? How is the evolution of heat by percussion accounted for? When a piece of steel is struck by a flint, how is the fire produced? How is the heat produced by friction accounted for?

heat produced by friction could not be connected with the decomposition of oxygen gas, nor with the increase of density, nor could it be caused by any change in the specific caloric of bodies. Others have also made experiments with a view to determine this question, but as yet no one has pretended to give any satisfactory explanation of its cause.

The *Condensation* of an elastic fluid by sudden pressure causes heat, as has already been explained, and illustrated by Fig. 15. The heat evolved in this case arises simply from the diminished capacity of the air for caloric, in consequence of its increased density.

CHAPTER III.

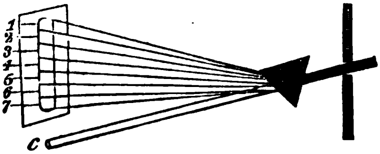
LIGHT.

100. THE next imponderable agent which falls under our notice is *light*. The investigation of the properties of light; its laws of reflection and refraction, and its effects on the sense of vision, are subjects belonging to the science of *Optics*. (*See Optics in Natural Philosophy.*) Some of the effects of light are however properly considered here, since they produce chemical phenomena.

Light may be decomposed, by means of a prism, into seven primary colors. The succession of these colors, beginning with the uppermost, is *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, *red*.

The decomposition of light only requires that a ray should be admitted through a small aperture into a room, and made to pass through a triangular prism, as represented by Fig. 24.

FIG. 24.



Solar Spectrum.

The direction of the ray toward the point *c*, will be changed by the refractive power of the prism, and at the same time it will be decomposed into the colors already named, the violet correspond-

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How does condensation produce heat? To what science does the investigation of the properties of light, with its effects on the sense of vision, belong? Why do some of the effects of light properly belong to the investigations of chemistry?

ing with 1, and the red with 7. It may be observed by the figure, that the red is refracted *least*, and the violet *most*, from the direction of the original ray, these two colors terminating the under and the upper parts of the spectrum.

These seven, are called the *primary* colors, since they can not by any known means be again decomposed, or separated into other colors. The whole seven are called the *solar spectrum*.

The heating powers of these several colors are different. Take a sensible air thermometer (Fig. 17) and move the bulb in succession through all the colored rays, waiting at each for the fluid to rise or fall, the thermometer will be found to indicate the greatest heat in the red ray, next in the green, and so on, in a diminishing ratio, to the violet.

When the thermometer is moved a little beyond the red ray, but in a line with the spectrum, the heat is still greater than in the ray itself. These last heating rays are invisible to the eye, and hence it is concluded that there exists in the solar beam a distinct ray which causes heat, but no light.

The illuminating power of each primary ray in the solar spectrum, is different from the other. This is proved by permitting the spectrum to fall on a large printed sheet, of the same sized type, when it will be found, that at the same distance, the parts illuminated by some of the rays can be read, while those illuminated by others are indistinct.

Light is capable of being absorbed by certain substances; of remaining in them for a time, and then of being extricated unaltered. Such bodies are called *solar phosphori*.

101. Photometer.—This term signifies "light measurer," and was invented by Dr. Leslie for the purpore of ascertaining the comparative intensities of light. In consists merely of a differential thermometer, with one of the balls elevated above the other, and left transparent, as usual, while the other ball is made of black glass, or is covered with India-ink. The clear ball transmits all the rays both of heat and light which fall upon it, and therefore its temperature is not affected; on the contrary, they are all absorbed by the black ball, and by

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Into how many primary colors may light be divided? What is the succession of these colors, beginning with the uppermost? How may the decomposition of light be effected? Which ray is most, and which is least refracted, from the direction of the original ray? What are these seven colors called? What are the whole called? What is said of the heating powers of the different rays? Is the greatest heating power in the red ray, or beyond it? Are the heating rays visible, or invisible? How is it proved that the illuminating powers of the different rays differ? What is the meaning of the word *photometer*? In what manner is it constructed? In what manner is it used?

heating and expanding the air within, causes it to press upon the colored liquid, which ascending toward the clear ball in the opposite stem, indicates the degrees of light to which it is exposed. The whole instrument is covered with a case of thin glass to protect it from currents of cool air.

It will be observed that the action of this photometer depends on the heat which the black ball absorbs from the light to which it is exposed.

PHOSPHORESCENCE.

102. Phosphorescence may be defined, the emission of light without sensible heat, or without combustion.

A considerable number of substances have the power of absorbing a quantity of light when exposed to the rays of the sun, and of emitting it again, so as to become luminous in the dark. Most substances lose this property in a short time, but acquire it again by another exposure to the sun, and this may be repeated any number of times. Several substances by this treatment become so luminous as to render minute objects visible in the dark. Canton's phosphorus is of this kind, and may be prepared as follows: Calcine common oyster shells in the fire for an hour; then select the purest and whitest parts, and reduce them to fine powder. Mix three parts of this powder with one of sulphur, and having pressed the mixture into a crucible, keep it red hot for one hour. Then let the crucible cool, and select the brightest and purest parts, which cork up in a dry vial for use.

When this composition has been exposed for a few minutes to the light of the sun, and then carried into the dark, it will be sufficiently luminous to show the hour by a watch dial.

The same property is possessed by compositions called Homberg's and Baldwin's phosphorus. The diamond, also, possesses this property, as shown by the celebrated experiment of Dufay, who, having exposed a diamond to the light, immediately covered it with wax, and on removing the wax, several months afterward, found that it shone in the dark.

103. PHOSPHORESCENCE BY FRICTION.—Some substances phosphoresce by friction, some by scratching, and others by heat.

What is phosphorescence? What are solar phosphori? What is said of the power of bodies to absorb and emit light? What is Canton's phosphorous? How is Canton's phosphorus prepared? What is necessary in order to make this substance shine in the dark? How did Dufay confine the light in a diamond? What is said of the phosphorescence of other substances?

That variety of carbonate of lime called *dolomite*, gives light on being rubbed. Loaf sugar mixed with whites of eggs and dried, as is done for the frosting of cake, emits a streak of light on being scratched with a sharp point. Several varieties of fluate of lime, and of marble, emit light when coarsely powdered and thrown on a hot plate of iron, so as to be seen in the dark.

A piece of tobacco-pipe, or a piece of quicklime, when heated by the compound blow-pipe, or by other means, to a degree which would only make other bodies red, give out a brilliant phosphorescent light, which is so intense as to become intolerable to the eyes.

104. Another kind of phosphorescence may be observed during the decomposition of certain animal substances. Thus, if a small piece of fresh herring, or mackerel, be put into a two ounce vial of sea water, or into pure water, with a little common salt, and the vial be kept in a warm place for two or three days, there will then appear a luminous ring on the surface of the water, and if the vial be shaken, the whole will give a phosphorescent light.

105. Light produces very material effects on the growth of all vegetables, from the most humble plant to the tallest tree of the forest. Plants vegetating in the dark are white, feeble, almost tasteless, and contain but little combustible, or carbonaceous matter. On exposing such plants to the light of the sun, their colors become green, their tastes become much more intense, and the quantity of their combustible matter becomes greatly increased. These changes are strikingly obvious, and, beyond all doubt, depend on the agency of light.

106. Light not only affects the natural, but, in many instances, the artificial colors of things. In this respect, however, its effects appear not to be reducible to any general law, for in some instances it destroys, and in others it augments, or even creates the colors of bodies.

On exposing bees-wax to the sun and moisture, its color is discharged, and it becomes white; it is also well known that the colors of printed goods, and of carpets, are changed, or faded by the same influence; and that the former mode of

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What is said of the phosphorescence of a piece of tobacco-pipe, or quicklime? How may a piece of fish be made to exhibit phosphorescence? How are plants affected by growing in the dark? What changes are effected by the light of the sun on plants which have grown in the dark? How are the artificial colors of things affected by light? To what do the colors of plants appear to be entirely owing?

bleaching, consisted in exposing the cloth to the united influence of light, air, and moisture.

107. On the contrary, the colors of plants appear to be exclusively owing to their exposure to light; and various chemical preparations, such as phosphorous, and the nitrate and chloride of silver, become dark colored, and even black, by the influence of light.

108. INFLUENCE ON CRYSTALLIZATION.—Light has also an important and curious influence on the crystallization of salts. Make a strong solution of the sulphate of iron, in water, and place it in a shallow dish. Cover one-half of the dish with a black cloth, and set it in a darkened room, permitting only a single ray of light to enter, so as to strike upon the solution in the uncovered part of the dish. Thus one-half of the solution will be exposed to the light, while the other half will be in darkness. After the dish has stood in this situation for a day or two, it will be found that no signs of crystallization are to be seen in that part of the solution which has been kept in the dark, while that part which has been exposed to the light will be completely crystallized.

109. PLANTS EMIT OXYGEN.—Another curious fact connected with this subject is, that plants emit oxygen gas through the influence of the sun's light. To make this obvious, fill a tall, glass vessel, such as a bell glass, with water, and invert it into another vessel of water. Then introduce into the bell glass some sprigs of mint, or any other plant of vigorous growth, and expose the whole to the action of the sun. Small bubbles of air will soon appear, as though issuing from the leaves of the plant. These will, one after another, detach themselves, and arise to the upper part of the vessel, and, on examination, the air thus extricated will be found to consist of very pure oxygen gas. (*See Oxygen.*)

In this experiment the water serves only as the means of collecting the oxygen, the water itself not being decomposed by the plant, but only the air which it contains. The air which we breathe contains a quantity of carbonic acid, which is decomposed by the organs of the plant, the carbon being retained, while the oxygen is emitted. (*See Vegetation.*)

What substances become dark colored by the influence of light? How is it shown that light has an influence on the crystallization of salts? How is it demonstrated that plants emit oxygen gas through the influence of the sun's light? Describe the chemical changes by which plants extricate oxygen gas.

CHAPTER IV.

ELECTRICITY.

110. The third imponderable agent is Electricity, including Galvanism.

The ancients knew nothing of electricity as a science. They knew, indeed, that amber and glass, when rubbed, would attract light substances; and about the beginning of the eighteenth century, it was discovered that a certain stone called *tourmaline*, would attract feathers and hair, when heated, and that some precious stones would do the same when rubbed. As an important science, electricity can claim no higher date than the age of Franklin.

111. Origin of galvanism.—Galvanism is of much more recent date than electricity. This science owes its name and origin to an accidental discovery, made by Galvani, an Italian, in 1791. Galvani was professor of anatomy at Bologna, and his great discovery seems to have been owing, indirectly, to the sickly condition of his wife. This lady, being consumptive, was advised to take soup made of the flesh of frogs, as the most delicate nutriment. One of these animals, ready skinned, happened to lie on a table in the professor's laboratory, near which stood an electrical machine, with which a pupil was making experiments. While the machine was in action, the pupil chanced to touch one of the legs of the frog with a knife which he held in his hand, when suddenly the dead animal was thrown into violent convulsions. This singular circumstance excited the attention of the sick lady, who was present, and it was communicated to her husband, who was out of the room at the time. Galvani immediately repeated the experiment, and soon found that the convulsions took place only when a spark was drawn from the electrical machine, the knife at the same time touching the nerve of the frog. He also ascertained, from further investigations, that the same contractions were excited without the agency of an electrical machine, provided he employed two metals, such as zinc and silver, one of which was made to touch the nerve, wihle the other touched the muscle of the frog. (*See Galvanism.*) It is from such a beginning, that the now important science of galvanism had its origin.

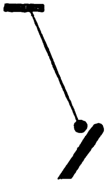
Was electricity known to the ancients as a science? What is the date of electricity as a science? To what circumstances does galvanism owe its origin?

Electricity, as an agent, is considered as an exceedingly subtle fluid, so light as not to affect the most delicate balances; moving with unmeasurable velocity, and pervading all substances. It is, therefore, its effects on other bodies only, or its phenomena, which it is in our power to examine.

112. FOUNDATION OF ELECTRICITY.—The simple facts on which the whole science of electricity is founded, may be stated in a few words.

If a piece of glass, amber, or sealing-wax, be rubbed with the dry hand, or with flannel, silk, or fur, and then held near small, light bodies, such as straws, hairs, or threads, these bodies will fly toward the glass, amber, or wax, thus rubbed, and, for a moment, will adhere to them. The substances having this power of attraction are called *electrics*, and the agency by which this power is exerted, is called *electricity*. Some bodies, such as certain crystals, exert the same power when heated, and others become electric by pressure.

FIG. 25.



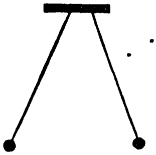
Electricity.

Although these are the simple facts on which the science is based, yet electricity exhibits a vast number of curious and interesting phenomena, depending on the variety and kind of machinery, and the quantity of the electrical influence employed.

When a piece of glass, or other electric, has been rubbed, so as to attract other bodies, it is said to be *excited*, and it is found that many substances are capable of this excitement, when managed in a peculiar manner.

113. The most common are, amber, glass, rosin, sulphur, wax, and the fur of animals. When an excited electric is presented toward a small ball made of pith, or cork, and suspended by a string, Fig. 25, the ball is attracted to the electric, and adheres to it for a moment. And if two such balls be suspended so as to touch each other, and the excited electric be made to touch one of them, the other will instantly recede from the one so touched;

FIG. 26.



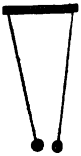
Electricity.

What is said of electricity as an agent? Is it in our power to examine electricity as a substance? How are we enabled to examine the properties of this agent? Describe the simple phenomena of electricity. What are electrics? What is electricity? By what process, besides friction, do some bodies become electric? When is an electric said to be excited? What are the most common electrics? What effect does an excited electric produce on a suspended pith ball? What is the effect on two pith balls in contact?

that is, they will mutually repel each other, and remain for a short time in the position shown by Fig. 26.

114. If, while they are in this position, one of them be touched with the finger, or a piece of metal, they will again instantly attract each other, and come together; and, if suspended apart, will approach each other, as represented by Fig. 27.

FIG. 27.



Electricity.

115. In the explanation of these phenomena, we suppose that all bodies are pervaded with the electric fluid, but that when in equilibrium, like air and water, it produces no obvious effects, and that it is only when this equilibrium is disturbed, or when some bodies contain more of the fluid than others, that electrical effects can be produced.

When an electric is rubbed with the hand, or other exciting substances, it receives a portion of the electric fluid from that substance; consequently, the electric then has a greater portion of electricity than is natural, while the hand, or other substance, has less. When two bodies are in different electrical states, that is, when one has more or less than the natural quantity, they attract each other. This is illustrated by Fig. 25, where the ball is represented as moving toward the excited electric.

But when two bodies have each more or less than the natural quantity, they repel each other. This is illustrated by Fig. 26, where the repulsion is caused by the communication of an uncommon share of the fluid from the excited electric to one ball, and from this ball to the other, and thus the two balls have more than their ordinary quantity of electricity, and are in the same electrical state.

On touching one of the balls with the finger, they again attract each other, because the finger deprives this ball of a part of its electricity, while the other ball is not affected, and thus the two balls are thrown into different electrical states. This is illustrated by Fig. 27.

When the balls are thrown apart by repulsion, what effect is produced by touching one of them with the finger? Explain these phenomena. Are all bodies supposed to be pervaded by the electrical fluid? Suppose an electric is rubbed by the hand, does it, in consequence, contain more or less electricity than before? Whence does the electric obtain this additional quantity of electricity? When do bodies attract each other through the influence of electricity? When do bodies repel each other through this influence? When the balls are thrown apart by repulsion, why do they attract each other on touching one of them with the finger?

THEORIES OF ELECTRICITY.

116. **Franklin's theory.**—To account for electrical phenomena, Dr. Franklin supposed, as above stated, that all terrestrial things had a natural quantity of that subtle fluid, but that its effects became apparent, only when a substance contained more or less than the natural quantity, which condition is effected by the friction of an electric. Thus, when a piece of glass is rubbed by the hand, the equilibrium is lost, the electrical fluid passing from the hand to the glass, so that now the hand contains less, and the glass more, than their ordinary quantities. These two states he called *positive* and *negative*, implying the presence and absence of the electrical fluid. If now a conductor of electricity, such as a piece of metal, be made to touch the positive body, or is brought near it, the accumulated fluid will leave this body and pass to the conductor, which will then contain more than its natural quantity of the fluid. But if the conductor be made to touch a negative body, then the conductor will impart a share of its own natural quantity of the fluid to that body, and consequently will contain less than ordinary. Also, when one body, positively, and the other negatively electrified, are connected by a conducting substance, then the fluid rushes from the positive to the negative side, and the equilibrium is restored.

This theory, originally invented by Dr. Franklin, will account satisfactorily for nearly every electrical phenomenon. There is, however, another theory, that of Dufay, which is still embraced by some writers.

117. **Dufay's theory.**—This theory supposes that there are two kinds of electricity, which are termed the *vitreous* and *resinous*, corresponding with the positive and negative of Franklin. This is founded on the fact, that when two pith balls, or other light bodies, near together, are touched by an excited piece of glass, or sealing-wax, they repel each other. But if one of the balls be touched by the glass, and the other by the wax, they will attract each other. Hence, Dufay concluded that electricity consists of two distinct fluids, which exist together in all bodies: that these two fluids attract each other, but that they are separated by the excitation of an electric, and that

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How are these phenomena accounted for on Dr. Franklin's theory? What are the positive and negative electrical states? Does Dr. Franklin's theory account for most of the phenomena observed? What do the positive and negative states imply? How does Dufay's theory differ from Franklin's? How do the vitreous and resinous electricities of Dufay correspond with the positive and negative of Franklin?

when thus separated, and transferred to non-electrics, as to the pith balls, the mutual attraction of the two electricities causes the balls to rush toward each other.

The electricity corresponding with the positive of Franklin, is called vitreous, because it is obtained from glass, while the other is called resinous, because it is obtained from wax and resin.

In respect to the merit of these two theories, we can only say here, that Franklin's is by far the most simple, and accounts equally well for nearly every electrical phenomenon.

118. CONDUCTORS OF ELECTRICITY.—Some bodies permit the electrical fluid to pass through them without difficulty. These are called *conductors*. They are the metals, water, and other fluids, except the oils, steam, ice, and snow. The best conductors are gold, silver, platina, brass, and iron. The conductors are non-electrics, that is, they show no signs of excitement when rubbed, under common circumstances. The electrics are non-conductors, that is, they will not conduct the electric fluid from a negative to a positive substance, and when excited, this fluid accumulates on their surfaces, because they have not the power of conducting it away. A body is said to be *insulated*, when it is supported by a non-conductor. A man standing on a stool supported by glass legs, or standing on a cake of wax, is insulated. When one body, or system of bodies, is in the positive state, the other part, or system, being contiguous, is invariably in the negative state. If one end of a stick of sealing-wax, or glass rod, be positive, the other end will be negative, and if one side of a plate of glass be positive, the other side will be negative. (*See Electricity, in Natural Philosophy.*)

119. ELECTRICAL MACHINES.—There are two kinds of this machine, called the *cylinder* and *plate* machines, depending on the form of the glass used to excite the electricity. The plate machine is considered much the best, since both sides are exposed to electrical friction, which, in the cylinder, only the outside can be excited.

The plate machine is here represented, Fig. 28. It consists of a plate of glass, *a*, *a*, turning on an axis of wood, by the

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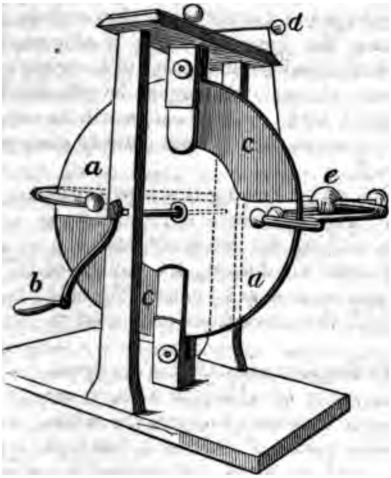
Why is one kind of electricity called vitreous and the other resinous? Which theory is said to be the most simple, and therefore to be preferred? What bodies permit electricity to pass through them without difficulty, and what are they called? What are the best conductors? What is the difference between conductors and non-conductors? Why does electricity accumulate when a non-conductor is excited? When is a body said to be insulated? When one side of a body is positive, in what electrical state will the other side be? Which is best, the plate or cylinder electrical machine? Why? Describe the plate machine, and its mode of action.

handle *b*, and supported by a frame fixed to a platform, also of wood. On opposite sides are two cushions, *c*, *c*, of leather, made to press against the plate by springs. From *d*, or some other part connected with the rubbers, a chain descends to the ground as a conductor of electricity to the plate. The electrical fluid accumulates on the surface of the prime conductor, *e*, which is insulated by a glass support, in order to prevent the escape of the fluid. By means of such a machine, especially if the cushions are covered by soft mercurial amalgam, large quantities of electricity may be accumulated. On turning the plate, sparks are seen to pass from its surface to the prime conductor, being attracted by sharp points of brass wire, which issue from the bright brass surface of the conductor. A plate of two feet in diameter, is sufficient for all ordinary purposes.

FIG. 28.



Electrical Machine.

CHEMICAL EFFECTS OF ELECTRICITY.

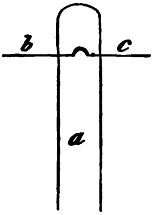
120. The chemical effects of electricity are most conspicuous in that form of this agency known under the name of *Galvanism*,

What are the effects of powerful electrical shocks on water? What are the effects of the same on a mixture of hydrogen and oxygen?

but there are many instances in which common electricity produces important chemical changes.

When powerful electrical discharges are passed through a glass tube containing pure water, by means of a gold or platina conductor, the water is decomposed, and resolved into its two elements, *hydrogen* and *oxygen*, (*see these articles*,) which immediately assume the gaseous form. If afterward the gaseous mixture thus obtained be submitted to electrical shocks, the reunion of these elements will again be effected, the hydrogen will be inflamed, while its combustion will be supported by the oxygen; the gaseous mixture will entirely disappear, and water will be formed.

FIG. 29.



Formation of Water.

The method of performing this experiment is shown by Fig. 29, where *a* represents a glass tube containing the two gases, and *b*, *c*, the two electrical conductors, the points of which approach so near as to permit the fluid to pass through the gases, from one point to the other.

To explain the phenomena of the decomposition of the water by electrical agency, we have to suppose that the two gases are naturally in opposite states of electricity, but that when united to form water, the electricity is in a state of equilibrium. When, therefore, water is submitted to the power of this agent, this equilibrium is destroyed, the negative gas, or oxygen, passing to the positive conductor, while the hydrogen, being in a positive state, passes to the negative conductor. Thus the fluid is decomposed, and assumes the gaseous form of its constituents.

The union of the two gases, and the consequent recomposition of water, is simply in consequence of the heat evolved by the electrical shock, as it passes through them. A degree of heat, by any other means, sufficient to inflame the hydrogen, would produce the same effect.

121. EFFECTS OF GALVANISM.—Precisely the same phenomena are produced by galvanism, both in respect to the decomposition of water, and the reunion of its elements. When

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Explain Fig. 29, and show how the latter experiment is performed. What is it necessary to suppose, in order to explain the decomposition of water by electrical agency? How does electricity act to decompose water from its two elements? What is said in respect to galvanism, as producing the same results as electricity? When sulphate of copper is submitted to the action of electricity, what phenomena ensue? How is this effect on the salts accounted for?

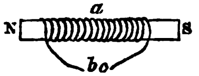
sulphate of copper is submitted to the action of a powerful electrical machine, the salt is decomposed, and the metal is revived around the negative wire. Other metallic salts undergo the same decomposition.

These effects arise from the different electrical states of the elements of which the salts are composed, the positive element being attracted to the negative conductor, and the contrary. It will be seen directly, that the identity of galvanism and electricity is proved by many similar results.

MAGNETO-ELECTRICITY.

122. Under electro-magnetism will be found the description of various magnetic phenomena produced by electricity. Mr. Faraday has demonstrated that electrical phenomena may also be produced by magnetism, and to these are applied the term *magneto-electricity*. For this purpose, let *a*, Fig. 30, represent a hollow spiral, or helix of copper wire, covered with silk or cotton thread. The ends, *b*, *c*, of this wire are connected with a delicate galvanometer (139.) A powerful magnetic bar N, S, is of such a size as to be easily introduced into the helix. Now, having connected the ends of the helix with the galvanometer, introduce the bar, and instantly the magnetic needle will be deflected in one direction, and on drawing it out, the deflection will be in the opposite direction. Now, as the galvanometer can only be moved by the motion of electricity in the helix, it is obvious that an electric current is produced each time the magnet is placed in it. Hence it appears, that if on the other hand electricity produces magnetism, so on the other magnetism produces electricity. By causing the pole of a powerful magnet to revolve near a coil of copper wire, or the wire to revolve opposite the pole of the magnet, an electric current may be established in the coil, which may be made sensible by sparks, shocks, and chemical effects.

FIG. 30.



Helix.

What is meant by magneto-electricity? Explain Fig. 30, and describe how electric effects may be produced by the magnet.

CHAPTER V.

GALVANISM.

123. It has already been stated, that the science of galvanism had its origin from an accidental discovery made by a pupil of Galvani, an Italian professor.

This subject was afterward prosecuted by Galvani, with the most untiring ardor, and with great success; and as his discoveries were made known, from time to time, to the scientific world, philosophers in all parts of Europe vied with each other in repeating his experiments, in varying them in all possible ways, and in making new experiments to account for the cause of the novel and surprising phenomena they observed. An account of these researches belong to the history of Galvanism, and can not be included in this concise epitome of the science.

124. **Professor Volta.**—It must suffice here to state, that the discoveries of Professor Volta, of Pavia, have contributed more toward the progress and development of the true principles of this science, than the united researches of all his colaborers. The discovery and invention of the *Galvanic* or *Voltaic* pile, the entire merit of which belongs to the Professor of Pavia, removed all doubt respecting the identity of electricity and galvanism, and is said to have been the result of deep meditation and reasoning. Volta's discovery was published in 1800, and since that time several modifications and many improvements in the mode of extricating the galvanic influence, have been made; they all, however, appear to be founded on his original invention.

To make this subject plain, it is necessary to state, that Galvani found, that when the different parts of a recent animal, as the nerves and muscles, were made to touch each other, and then the opposite ends of this series made to communicate by means of two different metals, signs of electricity were always apparent. Hence, Galvani concluded that the different parts of animals were in opposite states of electricity, and that the metals only served to restore the equilibrium. On the contrary, Volta

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What is said of the interest excited among philosophers by the discovery of galvanism? What philosopher, next to Galvani, has made the most successful researches on the nature of galvanism? Who discovered the galvanic pile? What is said concerning the identity of electricity and galvanism? From what experiment did Galvani conclude that the different parts of animals are in different electrical states?

maintained that the electrical excitement was owing to the contact of the two metals, and that the animal substances only served to conduct the fluid from the positive to the negative metal. And to show that this was the true theory of the phenomena, he proved by direct experiment, that when a piece of zinc and a piece of silver are placed in contact, and moistened, they are both excited, the zinc positively and the silver negatively. Thus, when a piece of silver, as a dollar, is placed on the tongue, and a piece of zinc under the tongue, and then their two edges made to touch each other, electricity will pass from the zinc to the silver, of which the person will be sensible, not only by a peculiar metallic taste, but by the perception of a slight flash of light, particularly if the eyes be closed.

The quantity of electricity evolved by two pieces of metal being exceedingly small, Volta tried the experiment of adding many pieces, arranging them in pairs, with a conductor between them, and found that the galvanic influence was increased in proportion to the number of plates thus combined.

Such attempts led him, finally, to construct the Voltaic pile already mentioned. This pile consists of a multiplied number of galvanic series, terminating at one extremity by a positive, and at the other by a negative conductor.

125. Simple galvanic circle.—The conditions necessary for galvanic excitation are entirely different from those under which common electricity is obtained. We have seen that electricity is accumulated when an electric or non-conductor is rubbed with the dry hand, or with another non-conductor, as a piece of silk, or fur. In ordinary galvanic excitation, such substances as are called *electrics* are not concerned.

These substances are all conductors of the electric fluid; one of them a simple conductor, the other two having each the additional power of different degrees of electrical, or galvanic excitement.

These three substances are usually zinc, water, and copper, and these, arranged in the order named, compose a *simple galvanic circle.*

The water, which is mixed with a small quantity of acid, not only serves as a conductor of the galvanic fluid, from the

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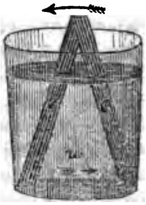
By what simple experiment is it shown that when moistened zinc and silver touch each other, electricity passes from one to the other? What is the principle on which the Voltaic pile is constructed? What is the difference between the substances used to collect electricity, and galvanism? What three substances usually compose a simple galvanic circle? What is the use of the water and acid employed in the extrication of galvanism?

positive to the negative metal, but also by acting slightly on the metals, is the efficient cause of the galvanic excitation.

FIG. 31.



Simple Circle.

126. This arrangement, together with the course of the electrical agent from one metal to the other, and through the water to the first metal again, will be understood by Fig. 31.

Suppose *c* to be a plate of copper, and *z* a late of zinc, touching each other at the top, and placed in a vessel of acidulated water. Then the action of the acid will produce an evolution of electricity from both metals, that from the zinc being positive, and that from the copper negative. The electrical fluid will therefore pass from the zinc, through the water, to the copper, and from the copper, by contact, to the zinc, and so in a perpetual circuit, in the direction of the arrows.

127. COMPOUND GALVANIC CIRCLE.—It is a multiplication of this principle; that is, by forming a series of simple galvanic circles, which compose the galvanic pile, or pile of Volta, already mentioned.

This *compound galvanic circle* is constituted by a series of simple circles, so united as to concentrate the influence of the whole at a given point. It may be constructed as follows:

128. CONSTRUCTION.—Provide three glass rods, say of two feet in length each, and fix these in an angular direction from each other in a base of wood. Provide, also, circular plates of copper and zinc, two or three inches in diameter, about the eighth or tenth part of an inch thick, and in number proportionate to the power of the intended pile. Next, cut out the same number of circular pieces of card paper, or of woolen cloth, that there are pieces of either metal, but less in size. Having thus obtained the elements of the pile, its construction consists in placing first on the base, or board, within the rods, a plate of copper, then on this a plate of zinc, and next, on the zinc, a piece of the paper, or cloth, dipped in salt water, or acidulated water, thus forming a single galvanic circle. The same arrangement is observed throughout the whole series; that is, copper, zinc, paper; copper, zinc, paper; except in the last circle, or top of the pile, which ends with the zinc. Fig. 32 represents such a pile, *a b* being the glass rods, and *z x* the

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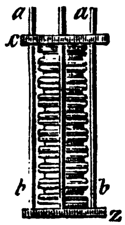
Explain Fig. 31, and show the course of the galvanic fluid? How is the pile of Volta constructed? After the frame is made, and the plates of metal and paper prepared, how is the pile then constructed? When does the pile operate most powerfully?

pieces of wood, the upper piece having holes to admit the rods, in order to make them secure.

FIG. 32.



Galvanic Pile.

Such a series affords a constant stream of the galvanic influence, but is always most powerful when first constructed, or before the plates become oxidated.

On this account, after having been some time in use, it requires to be taken in pieces, the plates cleaned from rust, and then again reconstructed, when it regains its original energy.

129. A pile composed of two dozen plates of each metal, will give a small shock, which, when taken by the hands, may be felt to the elbows. The mode of receiving the shock is by wetting the hands, and then having placed one of them in contact with the zinc plate, which terminates one end of the pile, touch with the other hand, the copper plate which terminates the other end of the pile. Or, these two plates may be touched with a wire, wound with a wet rag, and held in the palm of each hand. When experiments are to be made by passing the galvanic influence through any substance, this is done by connecting a wire with each terminating plate; the two movable ends of the wire being then brought near each other, and the substance placed between them, the fluid passes from the positive to the negative side, and so through the substance. These wires are called the *poles* of the Voltaic pile.

Any number of these piles may be connected together by making a metallic communication from the last plate of the one, to the first plate of the other, always observing to preserve the order of succession from the zinc to the copper, and from the copper to the zinc. In this manner a galvanic battery is constructed, the power of which will be proportionate to the number of plates employed.

130. The galvanic fluid, it ought to have been observed, is extricated only on condition that one of the metals employed be more easily oxidated, or more readily dissolved in an acid, than the other. Any two metals will form an effective galvanic apparatus on this condition, and it is always found that the

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How may the pile, after the plates have become oxidated, be made as powerful as at first? What is the mode of receiving the shock from the galvanic pile? When it is required to pass the electricity through a substance, how is this done? What are the wires, or conductors, called? How is a galvanic battery constructed? How must the metals differ, in respect to their affinity for oxygen, in order to evolve galvanism? In what electrical state is the metal which has the strongest affinity for oxygen?

metal having the strongest affinity for oxygen is positive, while the other is negative. Thus, any metal, except that which has the least affinity for oxygen of all, may form the positive or negative side, by having another metal, more or less oxidable than itself, placed in contact with it.

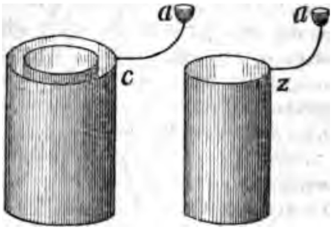
Copper, in contact with zinc, is negative, because zinc is most easily dissolved, or has the strongest affinity for oxygen of the two. But when copper is in contact with silver, it becomes positive, while the silver is negative; and, for the same reason, silver becomes positive when in contact with gold, or platina. The greatest effect is produced, other circumstances being equal, when two metals are placed together, one having the greatest, and the other the least affinity for oxygen, as zinc and platina.

Since the invention of Volta, a great variety of different methods have been devised, in order to extricate the galvanic fluid with greater convenience, or with greater power, and also to modify its action for different purposes.

131. ZINC AND COPPER CUPS.—But, perhaps, the most simple and convenient method of using small degrees of the galvanic power, is by means of cylindrical cups, composed of copper and zinc. By this arrangement, the exciting acid is contained within the cup of copper, while the zinc may be taken out and cleaned with little trouble; and besides, the apparatus may be constructed by almost any one who possesses a small sheet of copper, and another of zinc.

132. This arrangement will be understood by Fig. 33, where *c* is a double cup, made of two cylinders of sheet copper, of unequal size, placed one within the other, and soldered to the bottom, leaving the space of an inch between them, for containing the acid solution. The cup, *z*, is of zinc, and is inserted between the copper cylinders,

FIG. 33.



Galvanic Battery.

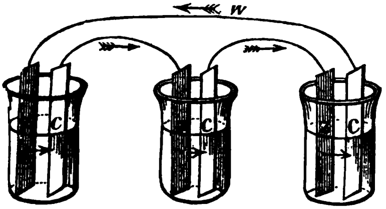
What will be the state of copper when in contact with zinc? What will be the state of copper when in contact with silver or gold? What metals will produce the greatest effect on this account? Describe the small battery, made of zinc and copper cylinders. What are the uses of the little cups, *a*, *a*, in the figure?

but is kept from contact with them by small pieces of cork, or wood. This is not fixed by soldering, but may be removed at pleasure for cleaning, the galvanic power being most intense when this is free from oxide. The small cups, *a*, *a*, are very useful appendages, for, by filling them with mercury, and inserting the ends of the conducting wires, the voltaic circuit may be continued, or broken at pleasure. These may be made of percussion caps, soldered on the ends of brass, or copper wire.

The exciting mixture for these cups may be made of a solution of sulphate of copper, in water, or of dilute sulphuric acid, to which is added a little common salt.

133. CUP BATTERY.—Another mode of arranging the galvanic apparatus, is by means of a row of glasses, each containing solution of common salt, or a dilute acid. In each glass is placed a plate of copper, and another of zinc, not in contact, but so connected by slips of metal, or by wires, that the zinc in one cup shall be connected with the copper of the next cup; the zinc in the second cup with the copper of the third, and the copper of the third with the zinc of the fourth, and so on through the series, except the terminating cups, which contain only a single plate each, one of copper, and the other of zinc. This arrangement will be understood by Fig. 34, where *c* and *z* mark the slips of copper and zinc, and *w* the wire by which the opposite poles are connected, the arrows showing the course of the fluid. The advantage of this method consists in the exposure of the two sides of the plates to the action of the acid; while, by soldering the plates, as in the construction of the galvanic trough, one of the surfaces of each metal is protected from the acid, and contributes nothing to the effect. But the bulk of this apparatus, and the danger of breaking the glasses, in case of transportation, prevents its general adoption.

FIG. 34.



Cup Battery.

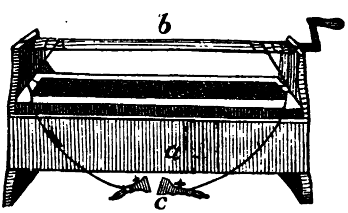
134. TROUGH BATTERY.—This formerly had the preference

Describe the mode of extricating galvanism by means of glass cups. Why is the apparatus made with cups objectionable? In what is called the trough battery, how are the plates united?

among all the known means of exciting the galvanic action, and although other, and in some respects, more convenient methods have been invented, still this, in many instances, is still employed. In the form in which it is at present employed, the zinc plates are flat, and are surrounded by thin sheets of copper, open at top and bottom. Formerly the trough was divided into cells, into which the dilute acid was placed. But it is found that when the copper surrounds the zinc, these divisions into cells are useless.

135. This apparatus is shown by Fig. 35, where *a* represents the trough containing the acid, above which are seen the plates of zinc and copper fastened to a frame, or case of wood, with varnished pasteboard between them, in order to prevent metallic contact. The galvanic influence is conveyed from one set of plates to the other by the fluid in the trough, which consists of one part sulphuric acid, diluted with forty or fifty parts of water.

FIG. 35.



Trough Battery.

136. By means of the windlass, *b*, the plates are let down into the acid, or removed from it with facility. The two wires connecting the opposite poles of the battery are seen at *c*, confined in little hand vices for the purpose of holding them, without contact with the hands. The trough to contain the acid may be made of mahogany, cemented on the inside, or what is better, of porcelain. This battery is supposed to contain twenty-five pairs of plates, and when first let down into the acid, will ignite steel wire, decompose water, or give a brilliant light, with charcoal points on the ends of the poles.

137. Connected batteries.—Where great power is wanted, any number of these troughs may be connected together, by passing a slip of copper from the positive end of one, to the negative end of the other trough. For the use of a laboratory, this is by far the most convenient, as well as the most powerful

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In the trough battery, how are the plates of metal brought into contact with the acid? What are said to be the advantages of this method? Why is this battery more powerful than the galvanic trough in which the plates are soldered together? What peculiar conveniences has this arrangement?

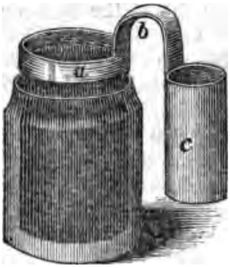
means of obtaining a large quantity of the galvanic fluid yet devised. When an experiment is finished, the operator, in a few minutes, can raise all the plates from their troughs by means of pullies, and thus they are suspended, ready to be let down again when wanted. The power, also, with the same extent of surface, is double that of the galvanic trough, where the plates are soldered together, since with the present method, the entire surface of each metal is exposed to the action of the acid. The plates can likewise be more readily cleaned, and the whole apparatus more easily kept in repair.

The Galvanic Battery of the Royal Institution of Great Britain, is constructed on the above plan. It is of immense power, consisting of 200 troughs of Wedgewood's ware, each containing ten cells, and receiving ten double plates of copper and zinc, each plate containing a surface of thirty-two square inches. The whole number of double plates is therefore 2000, and the whole metallic surface exposed to electrical excitation at the same instant, is equal to 128,000 square inches.

It was by means of this apparatus that Sir Humphrey Davy performed his brilliant experiments, and succeeded in decomposing the alkalies, and showing their metallic bases. (*See Potash and Soda.*)

138. Bunsen's battery.—In this arrangement, charcoal in contact with nitric acid, takes the place of platinum foil in other batteries. The carbon is in the form of a hollow cylinder, and is made by burning, or coking, bituminous coal in a proper iron mould. By soaking the coke in dissolved sugar, and calcining again, great compactness is given to the cylinder. This may be five inches in height, and two and a half in diameter, the sides being less than a quarter of an inch in thickness. Within the carbon cylinder, is placed one of porous clay containing a coil of zinc, both being included in a glass jar. The zinc cylinder, *c*, Fig. 36, is connected by the slip, *b*, of the same metal, with the zinc ring,

FIG. 36



Bunsen's Battery.

What number of double plates does the battery of the Royal Institution consist of? What important discoveries did Sir H. Davy make by means of this battery? What peculiarities in Bunsen's battery?

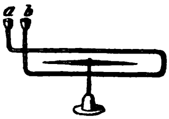
a, which surrounds the coke cylinder, the upper end of which is diminished, as the figure shows, in order to hold the ring.

This battery is charged by pouring within the clay tube a mixture of one part sulphuric acid and ten of water, and into the outer cell, a dilute solution of nitric acid.

GALVANOMETER.

139. This is an instrument for ascertaining the presence of a current of electricity, or galvanism, by the deviation which it occasions in the magnetic needle. The simplest galvanometer is a magnetic needle suspended between two parallel copper wires, connected with the galvanic battery. The wires should be insulated by covering them with silk, or cotton thread, and then varnished. The cups, *a*, *b*, Fig. 37, at the ends of the wires, are filled with mercury for the convenient insertion of the two poles, coming from the source of electricity, or galvanism. When this needle is placed parallel to the coil, and in the magnetic meridian, as represented in the figure, it instantly deviates when the electrical current passes through the wires, and the deviation is either to the east or west, according to the direction of the current. If several coils of the wire be passed around the needle, the two ends being left free, as in the figure, the effect on the needle will thereby be increased.

FIG. 37.



Galvanometer.

140. Graham's galvanometer.—This is a much more perfect than that above described, being indeed the most delicate galvanometer invented. It consists of a pair of magnetic needles, Fig. 38, suspended on the same axis, one above the other, as seen in the cut, their attracting poles being opposite to each other, so as to leave them little directive power. They are suspended by a single fiber of raw silk. The lower needle is inclosed within a circle formed by many turns of insulated copper wire, which is covered by silk or cotton, marked *b*, and of which *p* and *n* are its extremities. When the poles of a battery are connected with these wires, the insulated hank becomes a part of the connecting wire, and the lower needle is deflected. The current of galvanism proceeding in one direction above this needle, and returning in the opposite direction below it, conspire to produce the same movement; and the upper

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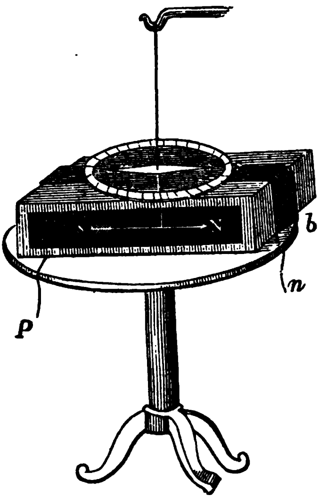
What is the galvanometer? What is the construction of this instrument? How is it employed? Describe the construction of Graham's galvanometer.

needle having its poles reversed, is deflected in the same direction by the wire below it, as the lower needle is by the wire above it. Every turn of the wire repeats the influence of the fluid upon the needles, so that the force is in proportion to the number of coils. This is an instrument of great delicacy, but requires much care in its construction. With the exception of the wire and magnetic needles, it may be made of wood, of which the best is mahogany, but any well seasoned wood will answer the purpose nearly as well for experiments with this excellent apparatus.

FIG 38.



Graham's Galvanometer.

CHEMICAL EFFECTS OF GALVANISM.

141. It is a singular, and, perhaps, unaccountable fact, that the extent of the continuous surface of the metals, from which the galvanic fluid is obtained, has an influence over its effects, when employed for various purposes. We should suppose, both from reasoning and analogy, that the amount of galvanic action would, in every case, be proportioned to the number of square inches of metallic surface, and that it would make no difference in the result, whether the individual pieces of metal were large or small. But experience shows that this is not the case. The effect of a battery composed of large plates, and one of small plates of the same extent of surface, is quite different. That composed of the large plates having the most intense chemical, or heating power, while that consisting of small ones has the greatest effect on the animal system. Thus, a man can bear with little inconvenience the shock from Mr. Children's battery, composed of plates six feet long, and two feet and a

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Is there any difference in the effect of a battery composed of large or small plates, when the extent of their surfaces is the same? What is the difference between the effects of large and small plates?

half wide; while he would be stunned, or perhaps killed, by the shock of the same amount of surface, were it divided so as to proceed from plates of only two or three inches in diameter. And yet Mr. Children's battery gives the most intensely brilliant calorific effects, while the calorific agency of the small plates is comparatively slight and insignificant.

The decomposing chemical effects of galvanism have been much more extensively employed than those of common electricity. Indeed, the decomposing power of electricity was little known before the brilliant discoveries of Sir H. Davy, by means of galvanism; but since that time, Dr. Wollaston has shown that most, if not all the chemical effects of the galvanic battery, may be produced by electricity.

The decomposition of water by means of electricity was effected by the Dutch chemists long before the discovery of galvanism. A description of the method of doing this has already been given, while treating of electricity. This seems to have been the most important chemical decomposition effected by electricity, before the discoveries of Galvani and Volta.

Since that period, the science of chemistry has owed to that of galvanism some of the most magnificent and important discoveries ever made in that science, viz.: the decomposition of the alkalies, and, as a consequence of this, other discoveries of great interest and value.

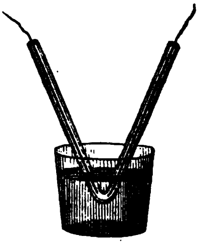
One of the most extraordinary facts belonging to the agency of galvanism, is the discovery that the elements of decomposed bodies follow an invariable law in respect to the electrical sides on which they arrange themselves. Thus, in decomposing water, or other compounds containing its elements, the hydrogen escapes at the negative poles, and the oxygen at the positive. In the decomposition of the salts (*see Salts*) and other compounds, this law is in every instance observed, the same kind of element being always disengaged at the same pole of the battery.

142. DECOMPOSITION OF WATER.—When a compound consists of two gaseous elements, they may be readily separated, and each gas obtained alone, by placing the compound in a bent tube, and then exposing it to the galvanic action.

This simple arrangement is represented by Fig. 39.

Will electricity produce the same chemical effects as galvanism? Was the decomposition of water effected by electricity before the discovery of galvanism? Of what use has galvanism been to chemistry? In the decomposition of water by galvanism, at which pole of the battery does hydrogen always escape?

FIG. 39.



Decomposition of Water.

It consists of a glass tube, bent as in the figure, a small orifice being ground at the angle so as to let in the water; or instead of this, two tubes may be used with their lower ends placed in contact. The tubes being filled with water, and their lower ends placed in a dish of the same fluid, the two platina wires proceeding from the two sides of the battery are passed through corks in the upper ends of the tubes, and pushed down, so as to come within about the eighth of an inch of each other. Care must be taken that the adjustment be such as to allow the gases as they ascend to come within the orifices of the tubes.

The battery being now set in action, small bubbles of gas will be seen to arise from the ends of the wires, but in different quantities. The tube from the negative wire will soon be filled with hydrogen gas, while the other in the same time will be only half filled with oxygen. This circumstance arises from the fact, that in forming water, these two gases combine in the proportion of two volumes of hydrogen to one of oxygen. Of course, therefore, when water is decomposed, the volume of oxygen is only half that of hydrogen.

In this experiment, the poles of the battery must be of platina, or gold, otherwise, if they are made of iron, or other oxidable metal, the oxygen combines with the metal instead of being extricated and rising up the tube.

When neutral salts, whether alkaline, metallic, or earthy, such as common salt, blue vitriol, or alum, are exposed to the action of a powerful battery, the same law is observed; the acid, which contains the oxygen, goes to the positive wire, while the bases, being alkalies, metals, or earths, are transferred with the hydrogen (for these salts always contain water) to the negative wire.

143. Transfer of elements.—But the most surprising effects of the power of this principle is exhibited when the compound is placed in cups connected with the two sides of the

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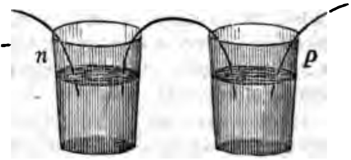
Describe the method of decomposing water by galvanism, and of retaining the two gases in a separate state. In performing this experiment, why is the tube on the negative side first filled with gas? In decomposing the salts, what law is observed in respect to the poles at which their elements are extricated?

battery, and the two constituents of the compound are transferred from one cup to the other.

If the solution of any saline compound, such as Glauber's salt, be made in water, and placed in two cups, one connected with the positive, and the other with the negative side of the battery, then, by making a communication between the cups, by means of some moistened asbestos, or cotton, and setting the battery in action, the two constituents of the salt will be transferred from one cup to the other.

Fig. 40.

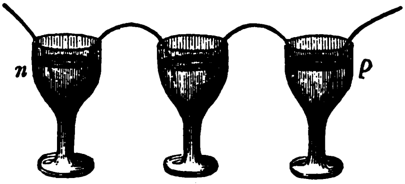


Galvanic Cups.

144. Fig. 40 will show the situation of the cups, the asbestos, and the galvanic poles of this experiment. Both cups contain a solution of Glauber's salt. This salt is composed of sulphuric acid, soda, and water. The cup, *p*, is connected to the positive side of the battery, by a wire, passing into the fluid, and the cup, *n*, with the negative side, in the same manner. The cups are connected by the moistened asbestos passing from the fluid of one to that of the other. When this arrangement is completed, and the battery has been some time in action, it will be found that the water in the positive cup will have an acid taste, while that in the negative cup will have an alkaline taste; and if the action be continued a sufficient time, all the acid contained in the salt will be found in one cup, and all the soda in the other.

145. Nor does it appear to make any difference in the result, at what part of the fluid circuit the salt to be decomposed is placed.

FIG. 41.



Galvanic Cups.

Explain Fig. 40, and describe how the elements of the salt are transferred from one cup to the other. In which cup is the acid, and in which is the alkali found?

This is proved by placing three cups in a line, and connecting them together by moistened asbestos, as shown by Fig. 41. If the Glauber's salt, or any other saline compound be put into the middle cup, and water into the others, and the two galvanic poles be connected with the other cups, *p* being the positive, and *n* the negative side, then all the acid will be transferred to the positive, and all the alkali to the negative cup, while the water in the middle cup will remain nearly in a state of purity. If the two outer cups be filled with an infusion of red cabbage instead of simple water, the operator can see the progress of his experiment, since the contents of one cup will be turned red by the acid, and the contents of the other green by the alkali.

146. SUSPENDS THE LAW OF AFFINITY.—A phenomenon of a still more extraordinary kind occurred to Sir H. Davy, during his experiments on this subject. For it was proved that the galvanic action was capable of suspending the laws of affinity, so that an acid might be conveyed through an alkaline substance, or an alkali through an acid, without any combination taking place between them, or either might be passed through a cup of infusion of cabbage, without changing its color. The three cups being arranged as in the last experiment, and connected together by films of moistened cotton, or asbestos, there was put into the negative cup, *n*, a solution of sulphate of soda, and into the other two cups, an infusion of red cabbage in water; this infusion being one of the most delicate tests of the presence of an acid or an alkali. After these cups, so arranged, had been for a short time placed in the galvanic circuit, the infusion in the positive cup became red, and afterward strongly acid, while that in the middle cup continued of the same color as at first. Thus, as the salt was decomposed, its acid passed through the middle cup without mixing in the least with the water it contained, otherwise its color would have been changed. On reversing the connections with the poles of the battery, the alkali of the salt was transferred to the opposite cup, the solution of which it tinged green, without in the least affecting the color of that in the middle cup.

On placing an alkaline solution in the middle cup, the acid

Describe Fig. 41. and show into which cup the salt is placed, and into which its different elements are transferred by the galvanic action. What is the advantage of filling the two outside cups with infusion of red cabbage? What extraordinary phenomenon is observed in respect to the suspension of the laws of affinity by galvanic action? Describe the experiment by which it was found that an acid or an alkali was made to pass through a cup of infusion of cabbage without changing its color. What are the other proofs showing that galvanic action suspends the action of affinity? How does Sir H. Davy account for these phenomena?

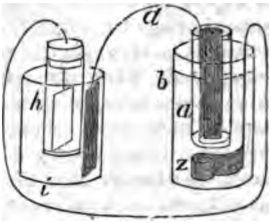
was transferred through it without combination ; and when an acid was placed in that cup, an alkali passed through it in like manner.

DECOMPOSING EFFECTS OF GALVANISM.

147. Bird's battery and decomposing cell.—It was formerly supposed that a large quantity of electricity, or intense electrical action, was required to effect the decomposition of elementary compounds; but it appears that a slight current of the fluid long continued, is sufficient to produce the same effects, in this respect, as a large quantity from a more extensive surface, and hence more costly apparatus.

The following description of Fig. 42, will make this distinctly understood. A glass tube, *a*, one and a half inches in diameter, and four inches long, having the lower end closed with a plug of plaster of Paris, is fixed by means of cork wedges, within the glass cylinder *b*, which is eight inches deep and two inches in diameter. A sheet of copper, *c*, six inches long and three inches wide, is coiled so as to go into the tube with the plaster bottom. To this the conducting copper wire *d* is soldered. A piece of sheet zinc, *z*, of the same size as the copper, is loosely coiled and placed into an outer cylinder, to this is soldered the conducting wire *e*.

FIG. 42.



Bird's Battery.

The counterpart of this, being the decomposing apparatus, the two being connected by the conducting wires, consists also of two glass tubes, or of a tube and cylinder, *h*, *i*; the bottom of the smaller one is stopped with plaster, or clay, and may be an inch in diameter, and three or four inches long; this contains a strip of platina foil, which is connected with the zinc plate in the other vessel by the wire *e*. This being the negative electrode of the battery, into this cell is placed the metallic solution for experiment. This conductor passing through a cork, stops the tube as the cut shows. The outer vessel contains a slip of amalgamated zinc, for the positive pole, or elec-

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Give an account of Bird's decomposing battery?

trode, which is soldered to the wire of the copper plate of the other vessel, or battery.

148. ACTION.—Having thus prepared the apparatus, fill the large cylinder of the battery with a weak solution of common salt, and the smaller one, containing the copper coil, with a saturated solution of sulphate of copper, the two fluids being prevented from mixing by the plaster bottom of the latter. Into the other cylinder, containing the zinc, at the end of the wire *d*, pour weak brine, and into the tube containing the platinum, place such metallic solutions as you wish to see reduced to the metallic state on the platinum. This apparatus, Dr. Bird states, will continue to afford a continuous current of galvinism for several weeks, and by it many, or most of the metallic salts may be reduced to their perfect metallic states. (*See Bird's Natural Philosophy.*)

149. THEORY OF GALVANISM.—To account for the phenomena of galvanism, Sir Humphrey Davy supposed that the elements of compound bodies were in different and opposite states of electricity, but that during their chemical union, an equilibrium existed in these electrical states. This theory we have already mentioned, in accounting for the decomposition of water by common electricity. But Sir H. Davy believed it to extend in general to all chemical compounds. To explain how the elements of bodies may be in this state, he supposed that each element is naturally possessed with a portion of electricity, whether it is in a state of combination or not; and that the elements, in this respect, naturally divide themselves into two classes, one of which is endowed with positive, and the other with negative electricity. In proof of this, it is found as an experimental fact, that oxygen, chlorine, iodine, (*see the latter article,*) and acids in general, are naturally negative, while hydrogen, the metals, and the metallic oxides, and the alkalies, are naturally positive. Thus it appears that bodies having the strongest attraction, or chemical affinity for each other, are naturally in opposite states of electricity, and that the supporters of combustion, oxygen, chlorine, and iodine, are all negatively electrified.

From such considerations, Sir H. Davy not only accounts for the chemical agency of the galvanic fluid, but also for that force called affinity, or chemical attraction, which impels bodies of

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In what state of electricity are oxygen, chlorine, iodine, and the acids generally? In what state are hydrogen and the metals? Are bodies having the strongest chemical affinity for each other, in the same, or in opposite states of electricity?

different kinds to unite and form compounds. Thus, oxygen being naturally negative, and hydrogen naturally positive, they unite with a force or energy proportional to the difference of their electrical states.

150. The decomposing force of the galvanic battery may readily be accounted for on the same principle; for if water be presented to any substance of a higher state of positive electricity than its hydrogen, then a decomposition would ensue, because the oxygen would leave the hydrogen, and attach itself to that substance for which it had the strongest attraction. The voltaic battery produces this effect, by offering to the two constituents of water stronger opposite electrical energies than these two substances have for each other. Thus, supposing the electrical force of hydrogen for oxygen to be equal to three, and that of oxygen to hydrogen to be equal to three, then they would combine with a force equal to six. But if we suppose the galvanic battery to offer to the oxygen a positive electrical energy equal to four, and at the same time to the hydrogen a negative energy equal to four, then it is obvious that their combining force would be overcome, and that the oxygen would fly to the positive, and the hydrogen to the negative poles of the battery, and thus that this compound would be reduced to its original elements; and we find that this is exactly what happens as a fact, when the water is exposed to the galvanic circle.

151. Positive and negative elements.—Among the ultimate elements which chemistry has developed, there is, at present, known to be twenty-two which are characterized by their electro-negative, and thirty-two by their electro-positive state, in relation to each other.

ELECTRO-POSITIVE.

Gold,
Platinum,
Iridium,
Osmium,
Palladium,
Silver,
Rhodium,
Mercury,
Copper,
Uranium,
Bismuth,
Tin,
Lead,
Cadmium,
Zinc,
Nickel,
Iron,
Cobalt,
Manganese,
Lantanium,
Cerium,
Zirconium,
Yttrium,
Glucinum,
Aluminum,
Magnesium,
Calcium,
Barium,
Strontium,
Lithium,
Sodium,
Potassium.

How is the decomposing force of galvanism accounted for?

ELECTRO-NEGATIVE.

Oxygen,
Hydrogen,
Nitrogen,
Sulphur,
Phosphorus,
Chlorine,
Iodine,
Fluorine,
Carbon,
Boron,
Silicon,
Selenium,
Arsenic,
Molybdenum,
Tungsten,
Antimony,
Tellurium,
Titanium,
Tantalium,
Vanadium.

OBSERVATIONS.—These substances, or elements, are negative or positive only in relation to each other, and their mutual affinities, appear in a chemical relation, to be in the ratio of the intensity of the difference of their comparative electrical states. As an example, we find potassium to possess the greatest affinity for oxygen of any known substance, and while this substance is energetically positive, oxygen, on the other hand, is as powerfully negative. In the list of negative elements, each is to be regarded as negative to all below, and positive to all above it, as placed in the table. Thus, hydrogen is negative with regard to nitrogen, but positive in regard to oxygen. With respect to the recently discovered metals, their places in the above arrangement have not yet been ascertained.

152. HEATING EFFECTS OF GALVANISM.—One of the effects of galvanic action is the evolution of heat; and where the action is strong, it is accompanied with light, but not otherwise.

There is a remarkable difference between the conditions necessary to the evolution of heat by galvanic action, and by common electricity. In common electricity, there is no production of heat, where the fluid moves through a perfect conductor, and without obstruction. When it moves along a rod of metal, no sensible heat, or light, is evolved, unless the conductor is too small for the quantity. But, in its passage through non-conducting substances, as air, or dry wood, both heat and light are a consequence.

But when galvanism passes through a perfect conductor, and the circuit remains entire, and when no light is evolved, there is still an elevation of temperature caused by its passage.

This is readily proved by making the two poles of the battery

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What is said in relation to the truth, or probability, of the electrical theory advanced by Sir H. Davy? Is it certain that in any case chemical attraction is caused by opposite electrical states? What is said of the heating effects of galvanism? What are the different conditions under which heat and light is evolved by electricity and galvanism? When galvanism is passed through a perfect conductor, what effect is produced? What is the effect when it is passed through water?

meet in a vessel of water containing a thermometer, when it will be found that the temperature of the water will soon be raised, and if the experiment be continued, the fluid will boil by the heat evolved.

If the battery consists of an extensive series of electrical circuits, very powerful calorific effects are produced by the passage of the fluid through metallic wires. Iron wire is melted and falls down in globules, and steel wire burns, with coruscations too brilliant for the unprotected eye.

The heating effects of galvanism seem to depend on the conducting power of the metal employed, the heat being in an inverse ratio to the power of the conductor. This is curiously illustrated by passing the fluid through a wire, or chain, composed of alternate portions, or links, of platina and silver, soldered together, when it will be found that the silver will scarcely be warmed, while the platina will be intensely ignited.

153. Children's battery.—It appears from some experiments made with Mr. Children's great battery, that the heat excited by voltaic action is more intense than that produced by any other means. Many substances were fused by it, which were exposed to the best wind furnaces, without any impression. A piece of platina wire, one-thirtieth of an inch in diameter, and eighteen inches long, became instantly red, then white hot, with a brilliancy insupportable to the eyes, and in a few seconds was fused into globules. Still, this battery had little effect on water, or on the human frame, the shock being felt no higher than the elbows.

154. But still more brilliant effects were produced by the battery of the Royal Institution, when pieces of charcoal were attached to its poles, and then brought near each other.

This battery, when the cells were filled with a mixture of sixty parts of water, and one part of nitric, and one of sulphuric acid, afforded the most splendid and impressive results. When pieces of charcoal, about one inch long, and the sixth of an inch in diameter, were placed in the circuit, and made to approach each other, a bright spark was seen to issue from one to the other, and, in a moment, the charcoal became ignited to whiteness. Then, by widening the space between the charcoal points,

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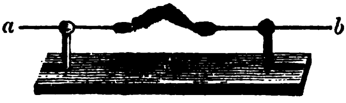
How are metallic wires affected by powerful galvanic action? When galvanism is passed through a chain, the links of which are alternately silver and platina, what is the effect on each metal? What is said of the power of Mr. Children's battery? What effect does this battery have on the human frame? What are the effects when pieces of charcoal are placed near each other, in a powerful galvanic circuit? Describe Fig. 43. What substances were fused by the battery of the Royal Institution?

a constant discharge continued, when they were four inches apart, affording a most brilliant ascending arch of light, broad in the middle, and terminating in points at the charcoal, resembling, in shape, two cones, applied base to base. The shape of this brilliant phenomenon is represented at Fig. 43, where *a* and *b*, are the poles of the battery, with pieces of charcoal attached to them, and, between these, the ascending arch of light. When any substance was held in this arch, it became instantly ignited; platina, one of the most infusible of all the metals, melted in it as readily as wax in a candle; quartz, sapphire, magnesia, and lime, all entered into fusion; and points of diamond and plumbago rapidly disappeared, seeming to evaporate with the heat.

FIG. 43.



Combustion of Charcoal.

CHAPTER VI.

ELECTRO-MAGNETISM.

155. It is perhaps a singular fact, that notwithstanding the very numerous and philosophical experiments made on the subject of Electricity, that no one, until at a comparatively recent period, ever noticed any connection between that power and magnetism. And yet electricity is never set in motion, unless magnetism is at the same time developed. This was first observed by Prof. Oersted, of Copenhagen, and has since become the source of an important series of discoveries, both to science and the arts.

If a suspended magnetic needle be brought near a wire, through which an electric current is passing, the needle will immediately deviate from its usual position, and assume a new one, depending upon the relative position of the needle and wire. On placing the electric wire *above*, and parallel to the magnet, the pole next to the negative end of the battery always moves toward the west; and when the wire is placed below, or *under* the needle, the pole turns toward the east. When the

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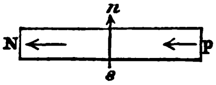
What is said of magnetism in connection with electricity? What takes place when a magnet is brought near an electrical current?

electric wire is on the same horizontal plane with the needle, no declination takes place; but the magnet shows a disposition to move in a vertical direction, the pole next the negative side of the battery being depressed when the wire is to the west of it, and elevated when it is at the east.

156. The magnetic phenomena of a wire transmitting electricity are such as to appear dependent upon the circulation of the magnetism at right angles to the electric current, so that if N P, Fig. 44, represent the negative and positive poles of the wire, transmitting a current of electricity in the direction of the horizontal darts, a current of magnetism will be established in the direction of the vertical dart, *n*, *s*, appearing to move round the axis of the electrical current; hence the name *vertiginous*, or rotary magnetism, sometimes applied to these phenomena. That such a rotary current exists under the conditions above described, is proved by the fact that, if a magnet has one of its poles loosely fastened, and the other free, the electric influence will give the free pole a circular motion; while under the same circumstances, the electric wire will rotate around the magnet.

FIG. 44.

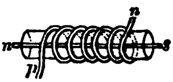


Rotary Magnetism.

If a steel needle be placed in contact with the electric wire, and parallel to it, the needle will acquire opposite magnetic poles upon its sides; but if it is placed at right angles to the wire, it will become polar, and possess all the properties of a permanent magnet, but slight in degree.

157. ELECTRICAL HELIX.—If a piece of copper wire be coiled by winding it around a solid, say half an inch, or less, in diameter, the folds not touching each other, an *electrical helix* will be formed, as represented by Fig. 45. This being connected with the two poles of an electrical battery, and a steel needle placed for a second within its folds, the needle will be found a strong, permanent magnet, and may be employed for any purpose for which magnetic polarity is required. Hence, we must conclude that the force of the magnet depends on the repetition of the electrical influence, since, as

FIG. 45.



Helix.

When the electrical wire is above the magnet, which way does it turn? When below, which way does it move? In what manner does the magnetism move with respect to the electrical current? How is it proved that an electrical rotary current exists? How is the electrical helix formed?

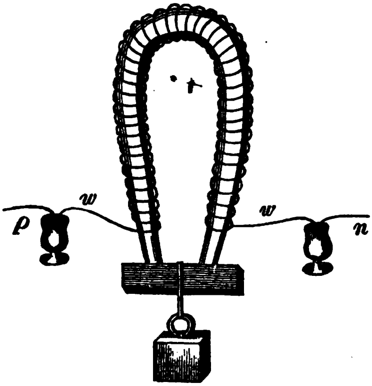
stated above, if the needle be merely crossed by a single wire, a weak magnet only is produced.

For these, and many other experiments, the little battery already described, consisting of cylinders of copper and zinc, is sufficient.

158. Temporary magnets.—These are formed by galvanic action on soft iron, the magnetic power remaining only while the influence of the battery continues.

The best form for this purpose is a U magnet, represented by Fig. 46. It is prepared by winding it with coils of insulated wire, or copper bell wire, covered with cotton, or silk thread, and then varnished. Such a magnet, with its armature, sustaining a weight, with the two ends of the wire dipped in little cups of mercury, and also the two poles of the battery in the same, is shown by the figure. It is hardly necessary to say that *w w* show the wires, and *p n* the positive and negative poles of the battery.

FIG. 46.



The U Magnet.

159. The effects of a magnet thus prepared, three or four inches long, will surprise those who are unused to such experiments, for having placed the armature near the magnetic poles, no attraction between them is produced, but on completing the galvanic circuit, the armature of soft iron instantly moves to the magnet, adhering with a force proportionate to its size and power. Magnets have been constructed in this manner which could suspend ten thousand pounds. On removing one of the poles of the battery, nothing but soft iron remains, and the weight falls instantly.

What is the use of the electrical helix? How is it shown that the magnetic force depends on the repetition of the electrical influence?

The battery for the above purpose may be made as shown by Fig. 33, the cups being six or eight inches high, and the outer one three inches in diameter.

CHAPTER VII.

ATTRACTION.

160. By *attraction* is meant that property in bodies which gives them a tendency to approach each other, whether they exist in atoms, or in masses. Attraction has received various names, according to the circumstances under which it is observed to act. Thus, that kind of attraction which extends to all kinds and quantities of matter, and to all distances, is called *attraction of gravitation.* This attraction extends reciprocally from one planet to another, and from all the planets [illegible] the fixed stars, and is the cause of the orbicular motion of the heavenly orbs. It also extends to all terrestrial masses of matter, and is the cause of their weight, or tendency to approach the center of the earth.

The force of gravitation is directly as the quantity of matter, and inversely as the square of the distance. The quantity of matter being given, and the attracting force at a certain distance, say four feet, being known, then this force will increase, or diminish, as the square of the distance. Thus, if one body attracts another, at the distance of two feet, with a force of thirty-six pounds, then, at the distance of four feet, its force of attraction will be only one fourth as much, or nine pounds, and so in this ratio, whatever the distance may be. (*See Natural Philosophy.*)

161. By *attraction* of *cohesion*, or *aggregation*, is meant that force which tends to preserve bodies in masses, by acting on the particles of which they are composed. This attraction is supposed to act only at insensible distances, as when the atoms of bodies touch each other, and only when the particles of matter are of the same kind.

162. *Chemical attraction* is that power which forces the particles of bodies of different kinds to combine and form a com-

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What is meant by attraction? What is attraction of gravitation? What are the laws of attractive force? Suppose a body is attracted with a force of thirty-six pounds, at the distance of two feet, what will the force be at the distance of four feet? What is meant by attraction of cohesion?

pound. This force is also called *affinity*, because this kind of union takes place only between particular substances. Like the attraction of cohesion, it acts only at insensible distances; that is, the particles of bodies must be brought into the immediate vicinity of each other before they will combine. But it differs from cohesive attraction in taking place only between heterogeneous atoms, or among particles of different kinds of matter. Several other kinds of attraction are described, (*see Natural Philosophy,*) but it is chemical attraction, or affinity, which must more immediately occupy our attention here.

AFFINITY.

163. Chemical attraction is a subject of the highest importance in the study of chemistry, since a knowledge of the whole science includes little more than an acquaintance with the laws and effects of affinity, that is, of chemical attraction and repulsion.

We have already noticed that this science is founded on experiment, and from deductions arising from facts thus discovered. Now, chemical experiments are only the means of discovering chemical affinities, and a knowledge of these affinities are the facts on which the whole science is founded.

164. By experiment we know that some bodies have an affinity to each other; that is, we know that on presenting them to each other, under certain circumstances, they will combine, and form a third substance, which differs from either of the first. We know, also, by the same means, that other substances, when presented together, in the same manner, will repel each other; that is, they will not combine, nor can they be made to unite, so as to form a third substance.

This kind of knowledge it is impossible for man to acquire without actual experiment; for by no process of reasoning could he ever determine beforehand, whether two bodies would attract or repel each other, any more than he could tell what they were composed of by mere inspection.

We know, for instance, that when we mix acid and water, the two liquids unite, or blend together; now, by reasoning from analogy, we should have the same grounds for believing that

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What is chemical attraction? How do cohesive and chemical attractions differ? In what respect is a knowledge of chemical attraction important? In what does a knowledge of the science of chemistry chiefly consist? What are the facts on which the science of chemistry is founded? How is it known that some bodies attract, while others repel each other? Is it possible to gain any knowledge of chemistry, except by experiment?

any other fluid would unite with water, that we had for believing that an acid would, and therefore that oil and water would combine, as well as acid and water. But experiment shows, that on this subject, neither reason nor analogy lends us the least aid, for, on mixing the oil and water, we find that they mutually repel each other, and though blended together by force, they again separate as soon as the force is removed.

It is, then, only by actual experiment that we can decide whether two bodies have an affinity for each other, and consequently, whether they are capable of forming a chemical compound, or not.

165. There are several circumstances which affect the results of chemical affinity, or conditions on which its action depends, which will be mentioned in their turn. There are, also, several kinds of affinity, which have received different names, depending on the conditions under which its action takes place. These appellations and conditions will also claim attention as they occur.

166. With a few exceptions, the first condition necessary to effect chemical combination is, that one or both the bodies should be in a fluid state; since, however strong the affinity of two bodies may be to each other, their particles can not unite unless they are free to move. Hence, to effect the combination of solids, their cohesion must first be destroyed, either by solution in a fluid, or by means of heat. The acids and alkalies have a strong affinity for each other, but on mixing them, even when in the finest powder, no chemical combination ensues, because, in all chemical compounds, the union takes place between the atoms of the combining substances.

But on pouring a quantity of water upon such a mixture, chemical action instantly ensues, and a third substance, differing entirely from the alkali or the acid, is the result of the combination. This compound is called a *salt*.

In like manner, if zinc and copper be reduced to the finest powder, and mixed ever so intimately by mechanical force, there will still be no intimate union between their particles. But if heat be applied so as to reduce them to a fluid state, they combine with considerable energy, and form a yellow alloy, called *brass*, which differs greatly from the zinc or copper of which it is formed.

What reason would there be to suppose, without experiment, that oil and water would not combine? What is the first condition necessary to effect chemical union? What is necessary, in order to effect the chemical combination of solids?

SIMPLE AFFINITY.

167. The most simple cases of affinity are afforded by the mixture of two substances which have the power of combining with each other, in any proportion. Water and sulphuric acid, or water and alcohol, form such combinations. What are termed *neutral salts*, which are formed by the union of a pure acid and a pure alkali, are instances of the same kind, only that they do not combine in all proportions. In a great variety of instances, after two substances have combined, when mixed alone, or without the admixture of any other substance, this first union may be destroyed by the intervention of another, or a third substance, having a stronger attraction for one of these substances then they have for each other. This forms an instance of what is termed *Elective Affinity.*

SINGLE ELECTIVE AFFINITY.

168. This is exercised when one composition is destroyed, and at the same time another is formed. There are many familiar examples of this kind of decomposition, some of which we witness almost every day. Camphor dissolved in alcohol, or in strong spirits, makes a transparent solution; but if water be poured into this solution, it instantly becomes turbid, and the camphor separates from its connection with the alcohol, and rises to the surface of the fluid. This separation takes place because the alcohol has a stronger affinity for the water than for the camphor, and the turbidness is caused by the insolubility of the camphor in water, in consequence of which it takes the solid form.

Soap is composed of oil, an alkali, and water. The oil and water have no affinity for each other, but the alkali has a strong affinity both for the oil and water, and consequently the three substances unite and form a compound. But if an acid be mixed with a solution of soap, the compound is decomposed, for the alkali has a stronger attraction for the acid than for the oil and water, and consequently the oil is rejected and rises to the surface, while the acid and the alkali form a new compound.

Why will not solids combine as well as fluids? In what manner may copper and zinc be made to combine? What are the most simple cases of affinity? Give an illustration of this affinity. What is single elective affinity? Give an example of the exercise of this kind of affinity. When water is poured into a solution of camphor in spirit, why is the camphor separated? What is the composition of soap? When an acid is mixed with a solution of soap, why does the oil rise to the surface?

169. WHY CALLED ELECTIVE AFFINITY.—This affinity is called *elective*, because, when one substance is mixed with several others it seems to manifest a choice between them, and elects one with which it unites, to the rejection of the others.

It is most probable that every substance has an affinity for many other substances. We know, indeed, that this is true in a great variety of instances, since experiment shows that one substance will form several compounds with other substances, in succession, and that these compounds may in succession be destroyed by the application of other substances which have a stronger affinity to the first.

170. As an example, suppose sulphuric acid, or the oil of vitriol, to be the first substance, or the one toward which several other substances have a chemical attraction, but in different degrees of force, then a compound formed between the acid and the substance having the least affinity, will be destroyed by the substance having the next stronger degree of affinity, and this second compound would be decomposed by the substance having the next degree of affinity, and so of every substance having a stronger attraction for the acid.

Thus, sulphuric acid has an affinity for *barytes*, *strontian*, *potash*, *soda*, *lime*, *ammonia*, and *magnesia*, and the force of this affinity is in the order in which they are named; that is, barytes has the strongest, and magnesia the weakest. A compound, therefore, of magnesia and sulphuric acid would be decomposed by the addition of ammonia, and one of ammonia and the acid, by the addition of lime, and so on; but none of these substances would decompose that formed between the acid and barytes, because these substances have the strongest affinity for each other.

No chemical facts appear, on first view, more simple or intelligible than those which are explained by the operation of elective affinity. But we shall find on a more minute examination, that this force, abstractedly considered, is only one of several causes, which are concerned in chemical decompositions, and that its action is modified, and sometimes subverted by counteracting causes, to be mentioned hereafter.

Why is this kind of affinity called elective? What is said relative to the attraction of one substance for many others? What are the substances named, as having an affinity for sulphuric acid, and in what order is the force of this affinity with respect to the substances? Suppose soda and sulphuric acid to be combined, which of the substances named would decompose the compound? Which of the substances named would decompose sulphate of barytes?

DOUBLE ELECTIVE AFFINITY.

171. This takes place whenever two compounds, each consisting of two ingredients, mutually decompose each other, and by a double interchange of these principles form two *new* compounds. We have seen that in single elective affinity, one new compound is formed by the addition of a single substance, while the ingredient thus rejected remains uncombined, or alone, in the solution. Thus, when lime is added to a compound of magnesia and sulphuric acid, the lime and acid unite, while the magnesia is rejected, and remains solitary in the solution, having nothing on which to bestow its affinity.

In double elective affinity, an interchange of the principles belonging to each compound is effected, and thus the old compounds are destroyed, and new ones formed; and it is curious and interesting to observe the consequences of what we should call the *likes* and *dislikes* of the particles of matter for each other, were they animated.

172. It often happens, that a compound of two ingredients can not be destroyed by the application of a third, or fourth ingredient, separately; but if the third and fourth be combined, and then the two compounds be brought into contact with each other, decomposition and interchange of principles will ensue. Thus, sulphate of soda is composed of soda and sulphuric acid, and is the substance called *Glauber's salt.* Now, when lime is added to a solution of this salt, there ensues no decomposition, because the soda attracts the acid more strongly than the acid attracts the lime. If muriatic acid be added to the same solution; there still follows no decomposition, because the sulphuric acid has a greater affinity for the soda, than the soda has for the muriatic acid. But if the lime and muriatic acid be previously combined, forming a muriate of lime, and this compound be added to the solution of the sulphate of soda, then a double decomposition follows, and two new compounds are formed out of the old ingredients. The lime of the muriate of lime, and the sulphuric acid of the sulphate of soda, having stronger affections for each other than the first has for muriatic acid, or the second for soda, mutually abandon their old connections, and having combined with each other, form a new

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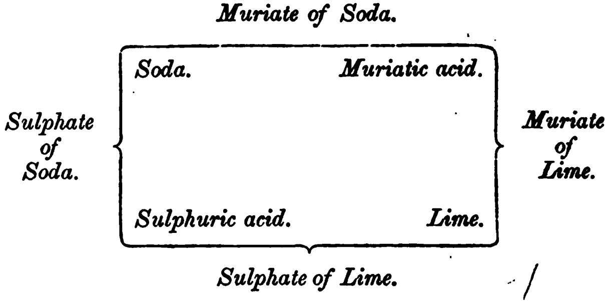
When does double elective affinity take place? In this kind of affinity, how many old compounds are destroyed, and how many new ones formed at the same time? Why does not lime decompose sulphate of soda? Why does not muriatic acid decompose sulphate of soda? What are the chemical changes effected when muriate of lime is added to a solution of sulphate of soda?

compound under the name of *sulphate of lime.* The soda and muriatic acid being thus rejected, and their former unions dissolved, they combine themselves anew, and form another compound, known under the name of *muriate of soda*, or common salt. These changes will, perhaps, be better understood by the diagram which follows:



On the outside of the vertical brackets are placed the names of the original compounds, sulphate of soda and muriate of lime, and above and below the diagram those of the new compounds. The upper line is straight, to indicate that the muriate of soda remains in solution, while the middle of the lower one is directed downward, to show that the sulphate of lime is precipitated, or falls to the bottom of the vessel.

CAUSES WHICH COUNTERACT OR MODIFY THE EFFECTS OF CHEMICAL AFFINITY.

173. It has been stated that the effects of chemical action are often modified, or even subverted, by counteracting causes. The principal causes which have a tendency to counteract chemical combinations are *cohesion*, *quantity of matter*, *elasticity*, *and gravity.*

COHESION.

174. By cohesion, we mean that attractive force by which the particles of bodies are kept together, and in consequence of which, masses are formed. This force may modify, or entirely

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What are the names of the compounds formed by the decomposition of sulphate of soda and muriate of lime? Explain the diagram illustrating these changes. What are the principal causes which promote or counteract chemical changes? What is meant by cohesion? How does cohesion prevent solution? Why will the same substance in powder enter into solution more readily than when in the mass?

counteract that of chemical attraction; for the more strongly the particles of any substance are united, the greater the obstacle to a chemical union with those of other bodies, because the successful effects of affinity depend on a mutual penetration of particles. Hence, the formation of chemical compounds, with some exceptions, requires that at least one of the ingredients should be in the state of a liquid, so that the particles of each should have free mutual access. Where the affinities are strong, and the cohesion slight, the union is effected with considerable energy under such circumstances. Thus, masses of carbonate of ammonia, of considerable size, will be dissolved by nitric acid; but when the force of cohesion is great, it is a strong barrier to the operation of affinity. Thus, a mass of carbonate of lime, or marble, will remain for days in an acid, when, were it reduced to powder, it would be dissolved in a few minutes.

In all such cases, therefore, mechanical division is required before rapid solution, or intense chemical action, can be effected. Cohesion being thus overcome, solution is readily accomplished, because the solid now presents a greater extent of surface to the action of the fluid.

HEAT.

175. Heat is another means of counteracting the cohesion of bodies, the repulsive power of caloric being indeed the great opposing force of that of cohesion, and provided its quantity be proportionate to the force of attraction, will so overcome it as to render all solid bodies liquid. Different substances, it is obvious, require different degrees of heat for this purpose. Thus, the cohesive force of such bodies as are called liquids, is so counteracted by the heat of ordinary temperatures, as to make their particles easily movable among each other, a circumstance on which their liquidity depends. But many of these substances, such as water and oil, by the abstraction of heat become solids, because then the repulsive force of caloric becomes less than the attractive force of cohesion. On the contrary, in bodies which we term solids, the attractive force of cohesion is greater than the repulsive power of caloric, and hence at all ordinary temperatures, their particles are fixed and

What is the opposing force to cohesion? What is the cause of fluidity in bodies? How might all bodies be made fluid? Why does water become solid when caloric is abstracted from it? On what does the solidity of bodies depend? What is the only means by which metallic alloys can be produced?

immovable among themselves, a circumstance on which their solidity depends.

We have stated that the exercise of affinity depends on the state of the substances concerned, and that in general, one of them must be in a fluid state. In most instances, solution is effected in some liquid, as an acid, alcohol, or water. But to produce metallic alloys, the metals must be brought to a liquid state without changing their properties, and this can be effected only by means of caloric. For this purpose, it is only necessary that one of the metals, viz.: that requiring the highest degree of heat, should be melted, and the other thrown into this in small pieces.

QUANTITY OF MATTER.

176. Experiment teaches that quantity of matter exerts an important influence over chemical decompositions and solutions. Thus, we know precisely how much sulphuric acid, for instance, will neutralize a given quantity of potash, when in a free state. But if the same quantity of potash be first combined with nitric acid, forming nitrate of potash, or saltpeter, then more of the sulphuric acid is required to detach this quantity than before, probably, because some force is employed to destroy the union previously existing between the nitric acid and the potash, and also because the affinity of the two substances for each other diminishes when both are nearly saturated.

In making a solution of a metal in an acid, it may be observed, that the chemical action is much more energetic at the beginning of the process than afterwards, and that if no more acid be added, than is just sufficient to dissolve the metal, the action finally becomes so feeble as to require a day or two to complete the combination. But if, in this state, more acid be added, the action again becomes brisk, and the metal is soon dissolved.

ELASTICITY.

177. Cohesion being found an obstacle to the exercise of affinity, it might be expected that the contrary state, that is, the absence of cohesion, would facilitate chemical combinations; but experiment determines otherwise. In the elastic fluids, such as the gases, and common air, cohesion may be considered as entirely wanting. But bodies of this kind, though having a

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What is said of the influence of quantity of matter on chemical combinations? Explain how quantity of matter is illustrated by the solution of a metal in an acid. Does the elastic state facilitate chemical combinations?

strong affinity to each other, show little disposition, under ordinary circumstances, to combine. Thus, oxygen and hydrogen, though in different electrical states, may be mixed together in the same vessel for any period of time, without the least symptom of combination. The reason of this is probably owing to the distance of their particles, which prevents that near approach to each other required to come within the sphere of mutual attraction; for if the two gases be subjected to pressure by means of the little instrument called a fire pump, Fig. 16, they unite with explosive energy.

The elastic property not only opposes the chemical union of bodies, but is often an agent by which their decomposition is effected when exposed to the influence of caloric. Thus, substances containing a volatile and fixed principle, are sometimes decomposed by heat alone, because the repulsive force of caloric removes the elements of the compound beyond the influence of mutual attraction, and the volatile element makes its escape in consequence. Many of the salts, composed of an alkali, or a metal, and an acid, and water, are readily decomposed by heat alone. The water is first turned to steam, and escapes by its elasticity, leaving the salt opake, and as the heat is raised, the acid is converted into vapor, and escapes in the same manner. On the same principle, oxygen is obtained from manganese, from nitre, and several other compounds, where it exists as a principle.

GRAVITY.

177. When the difference between the weight of the two bodies is great, this circumstance opposes their chemical combination. Thus, when common salt is thrown into water, it sinks to the bottom, where the water soon becomes saturated, and will dissolve no more; but if the water be agitated, the whole will soon dissolve. It is found, also, that metals differing widely in their specific gravities, when melted together, do not mix equally, unless they are stirred, because the heavier metal settles to the bottom.

CATALYSIS.

178. A new chemical law, not within the ordinary force of affinity, has lately attracted attention. It has been called by Ber-

What is the most probable reason that gases having an affinity for each other do not unite, when mixed under ordinary circumstances? How may oxygen and hydrogen be made to combine? How does caloric act to separate a volatile from a fixed principle? What is meant by Catalysis?

zelius the *Catalytic force*, and the effect of its action *Catalysis*, from two Greek words meaning to *unloose downward*. Graham says that a body in which this power resides, resolves others into new compounds, merely by contact with them, or by an action of presence, as it has been termed, without gaining or losing any thing itself. Thus an acid converts a solution of starch, at a certain temperature, first into gum, and then into sugar of grapes, although no combination takes place between the elements of the acid, and those of the starch, the acid being found free, and undiminished in quantity, after effecting the change.

A much more signal and striking instance is that effected by platinum sponge in causing the union between hydrogen and oxygen. In this case, the hydrogen is ignited by merely bringing it into contact with the cold platina, and this may be continued any length of time without the least change in the metal. The student will see this illustrated hereafter. This force only applies to particular substances, so far as at present known, but may eventually lead to important results in chemical investigation.

CHANGES PRODUCED BY CHEMICAL COMBINATIONS.

179. By *chemical combination* is meant a union between two or more substances of different kinds, so intimate that they can not again be separated by mechanical means. Thus, if clay or chalk and water be mixed, the mixture will for a time be turbid, or opake, but if suffered to stand for a day or two, the clay or chalk will settle to the bottom of the vessel, and the water above will become transparent. But if water be mixed with an acid, or with salt, or with sugar, the union becomes permanent, nor will rest, or filtration, or any other mechanical means, separate either of these ingredients from the water. Hence the distinction between mechanical mixture and chemical union. In the first, no affinity between the substances exists, and therefore no union takes place, and the chalk or clay falls to the bottom of the vessel. In the second, there is a combination between the particles of which the substances are composed, owing to the affinity existing between them, and hence they

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What examples of this force are mentioned? How is the decomposition of a fluid effected by heat? What is said of gravity in opposing chemical union? How does common salt, in water, illustrate this principle? What is said of the combination of metals in this respect? What is meant by chemical combination? What is the distinction between mechanical mixture and chemical union? Why will not chalk and water combine permanently? When water and sugar are mixed, why does not the sugar settle to the bottom of the vessel?

are not separated, except by a stronger force than that of the existing affinity.

180. Intense chemical action.—The changes that accompany chemical action are in some proportion to its intensity. In the instances above named, where water is mixed with a small quantity of acid, or salt, this action is feeble, and the sensible changes produced inconsiderable, being only a slightly acidulous, or saline taste, given to the water. But in cases where the chemical action is intense, the changes produced in the combining substances are often great in proportion. Thus, when the two gases, oxygen and hydrogen, are burned together, their combination is attended with most intense chemical action, by which the highest degrees of heat are evolved, and at the same time the change produced is no less than the condensation of two elastic gases into the fluid water.

Many substances which are highly corrosive, in a separate state, become mild, and lose all their acrid qualities by combination with each other. Sulphuric acid and potash, for example, are highly caustic substances. They both act with great energy on animal and vegetable bodies, producing decomposition and total destruction of texture. The acid turns the blue colors of vegetables to red, and the alkali turns these colors to green. But on mixing these substances together, they entirely destroy the caustic qualities of each other, and there results a solid compound, called *sulphate of potash*, which is mild to the taste, and neither acts on animal or vegetable bodies, nor changes the colors of the latter. This is called a *neutral* salt, because the substances of which it is composed thus neutralize the active properties of each other.

When the opposing properties of chemical agents are thus destroyed by combination, they are said to *saturate* each other, and it is found that the acrid and caustic qualities of all the acids and alkalies are weakened in proportion as one is added to the other, until the point of saturation is attained, when the compound becomes neutral, and is not affected by a further addition of the acid or alkali, which forms a part of its composition.

181. Change of bulk—A change of *bulk* is also, in many instances, the result of chemical union, so that the two bodies

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Is there any proportion between the intensity of chemical action and the changes produced thereby? What illustrations of this law are given? What effect does combination sometimes have on the corrosive properties of bodies? Give an illustration of this effect. What is the composition of sulphate of potash? What is a neutral salt? When are substances said to saturate each other?

after combination, do not occupy the same space as before. Thus, when a pint of sulphuric acid is mixed with a pint of water, the chemical action is so great as to raise the thermometer above the boiling point, and the resulting compound will not measure two pints, as before the mixture, but considerably less.

When zinc and copper are fused together, the resulting alloy has a specific gravity greater than the medium specific gravities of the two metals, showing that their bulks are diminished by the union. The same happens when alcohol and water are mixed; and in general it is found that the resulting body, after chemical combination, has a greater specific gravity than the mean of its components.

182. CHANGE OF COLOR.—Another *change* often produced by the exercise of affinity, is that of *color*. The alloys of any two metals do not exhibit the mediums of their two colors. Thus, the *white* metal, zinc, and the *red* one, copper, when melted together, form the *yellow* compound, brass. The colors of the metallic oxides differ according to the quantities of oxygen they contain. The *black* oxide of mercury contains 200 parts of the metal and eight parts of oxygen, while the same quantity of metal combined with sixteen parts of oxygen, forms the *red* oxide of mercury. We have already had occasion to notice, that *blue* vegetable colors are changed to *red* by acids, and to *green* by alkalies; and in addition to this, we may state generally, that all vegetable colors are changed, more or less, by the application of these agents.

183. CHANGE OF FORM.—There is still another change, which is the effect of chemical affinity, and is often highly important; this is the change of *form*. Of this change chemistry exhibits a great variety of examples, many of which are highly curious and interesting. Thus, if a saturated solution of muriate of lime in water, be mixed with a small quantity of sulphuric acid, the two fluids immediately become a solid. This change is produced by the exercise of affinity. The muriate of lime is composed of lime and muriatic acid, and of this salt water will dissolve a large quantity and still remain fluid. The sulphuric acid has a stronger attraction for lime than the muriatic has,

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What is said of change of bulk as a result of chemical action? Suppose a quantity of water and sulphuric acid are mixed, will they occupy the same bulk that they did before the mixture? Will the bulk be greater or less than before? In chemical combinations, is the resulting body more or less dense than the medium density of its components? What is said of the change of color produced by chemical combinations? Is change of form ever effected by chemical combinations?

and the sulphate of lime is nearly insoluble in water. When, therefore, the former acid is added to the solution, a sulphate of lime is formed, which, in a spongy form, occupies the whole vessel. On the contrary, if equal parts of alum and acetate, or sugar of lead, be rubbed forcibly together in a mortar, they form a compound mass which is nearly fluid. The cause of this change from the solid to the semi-fluid state, is also easily explained. The alum and sugar of lead contain a quantity of water, called the water of crystallization. When they are forcibly rubbed together, the elements of which they are composed unite in consequence of mutual affinity, and thus the water of crystallization is set free, and occasions the partial fluidity of the mixture. The great changes which the two gases undergo in the formation of water, have already been mentioned. Similar changes, so far as respects the *condensation* of elastic fluids and liquids, are phenomena which are frequently witnessed in experimental chemistry. Thus, water absorbs about 5,000 times its own bulk of the gas called ammonia, which is in this manner condensed, and forms a part of the liquid. The compound thus formed is known by the name of *spirit of hartshorn.* Quicklime, in the process of slaking, absorbs a large quantity of water, which by the combination becomes solid, and forms a part of the dry lime.

184. INCREASE OF BULK.—In the formation of the gases, on the contrary, there is an immense increase of bulk. When water is decomposed and made to assume its elementary gaseous form, there is an increase of bulk nearly equal to 2,000 volumes. That is, a cubic inch of water contains 662 cubic inches of oxygen, and 1,325 cubic inches of hydrogen; thus the volume is increased 1,987 times by the decomposition. The explosion of gunpowder is another example of the vast increase of volume by chemical decomposition.

FORCE OF CHEMICAL AFFINITY.

185. Although it is ascertained, by means already described, that the affinity of one body for a number of others, is not of equal force, yet we are ignorant *how much* difference there is in the forces of these different degrees of affinity.

The only means of deciding this question is to observe the

How is the change of form accounted for when sulphuric acid and muriate of lime are mixed? How is the change of form explained, when alum and acetate of lead are forcibly mixed? What is said of the condensation of ammonia by water, and the condensation of water by slaking lime? How many times more bulky are the gases of which water is composed, than water itself?

tendency which several substances have to unite with the same substance, under similar circumstances. Oxygen, for instance, as a universal agent, might be selected as a standard, and the force of affinity between this and other bodies be estimated by their degrees of oxidation under the same circumstances. We know that there is an immense difference between the forces with which different bodies attract this principle. Some of the metals, for instance, absorb oxygen with such avidity, that they can not be preserved in their metallic state when exposed to the atmosphere, even for a short time; while others have so little affinity for this principle, that they can not be oxidated without the most energetic means. Thus, potassium (*see this word*) attracts oxygen with such force as to decompose water, at common temperatures, by absorbing it from the hydrogen; while the affinity of platina, or gold, for this principle, is so weak as not to attract it at all, except at the highest degrees of heat, or from acids which impart it most easily.

186. DEGREES OF ATTRACTION IN THE METALS.—We may constantly observe the effect of the different forces with which several metals attract oxygen in the common affairs of life. Thus, iron and lead, when exposed to the moisture of the atmosphere, soon tarnish, and after a time, by the absorption of oxygen, their surfaces become covered with rust, or the oxides of iron and lead. But silver and gold, when exposed in the same manner, continue bright and untarnished for years, as may be observed in the points of lightning-rods, and the gilded vanes and balls of church steeples. This difference can only arise from the different forces with which these metals attract the oxygen of the atmosphere.

There is no department in chemistry, either as a science, or an art, which so much needs the investigation of able men as this. Tables of affinity, showing at once the force of attraction between different chemical elements, would enable the inquirer, without further experiment, to decide what substance would decompose any given compound, and therefore how to separate, or combine, the different principles of bodies for a vast variety of purposes. Tables to a very limited extent have already been constructed for such purposes, but the difficulty and magnitude of this subject seems to have deterred the more modern chemists from engaging in this extensive department of the science.

How might the force of affinity be ascertained? How do we know that there is a great difference between the forces with which bodies attract oxygen? How is this difference illustrated? How is it shown that iron and lead attract oxygen with greater force than silver and gold?

CHAPTER VIII.

INDEFINITE AND DEFINITE PROPORTIONS.

187. It is ascertained by experiment that some bodies unite in unlimited, or indefinite proportions, while others combine in proportions which are always limited or definite.

The discovery of the laws of definite proportions is one of the most important and wonderful among the great and brilliant achievements in modern chemistry. It is sufficient of itself to convince any reasoning mind, that order and system pervade the universe, and that the minutest atoms of matter, and the vast orbs that move round the heavens, are equally under the control of the invariable laws of the Creator.

INDEFINITE PROPORTIONS.

188. When we mix water and alcohol, or water and any of the acids, they unite in any proportion. Thus, a drop of acid will combine with any quantity of water, and water will unite in the same manner with alcohol, or acid. This principle may be tested by direct experiment; for if a gallon of water be tinged blue by a vegetable color, a few drops of sulphuric acid will turn every drop in the gallon to a red color, thus proving, that this small quantity of acid has diffused itself through the whole mass. By similar experiment it can be shown that a small quantity of water will diffuse itself through a large quantity of acid. These examples prove that some bodies combine in unlimited proportions on both sides.

Other combinations appear to be limited on one side, and unlimited on the other. Thus, common salt, and other saline substances, will dissolve in water in any proportion short of the point of saturation, after which, if more be added, it will fall to the bottom of the vessel and remain solid. The greatest proportions in which water and common salt combine, are those of 100 of the former, with 40 of the latter; but the smallest quantity of salt will diffuse itself through the largest quantity of water, and the probable reason why salt does not unite with

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What would be the use of tables, showing the force of attraction between different chemical elements? What is said of the discovery of the laws of definite proportions? What substances are mentioned, which combine in unlimited proportions? How is it proved that a few drops of acid will diffuse itself through a large quantity of water?

water in every proportion, is, that its cohesion resists the feeble affinity of the fluid after it becomes saturated.

189. UNLIMITED PROPORTIONS SHOW FEEBLE FORCE.—In all cases where bodies combine with each other in every proportion, or where the proportions are limited on one side, and indefinite on the other, the force of affinity by which such compounds are formed is feeble, and the compounds themselves often differ but little from the original ingredients. Thus, alcohol and water combine in all proportions, but the union produces only a modification of the qualities of each, the degrees of which depend on the proportions of the mixture, and the force of affinity between them is so weak, that distillation, by a gentle heat, entirely destroys their union. Solutions of the salts, sugar, acids, and many other principles, are examples of the same kind; a moderate heat, and sometimes evaporation, without heat, will dissipate the water and leave the other ingredients in their former state.

In these, and a great variety of other instances, although the force of affinity is slight, still there is a wide difference between such compounds, and mere mechanical mixtures, since the latter are separated by rest, while the ingredients of the former are not separated by rest, filtration, or any other mechanical means.

These solutions, or combinations, formed by feeble affinities, resemble mixtures in respect to the slight changes which their ingredients undergo by uniting, while they resemble chemical compounds in respect to the inseparable nature of their union, by mechanical means.

190. The writer of the article *Chemistry*, in the Library of Useful Knowledge, has called such slight combinations *chemical mixtures*, in order to distinguish them from compounds formed by energetic affinities, and which come within the law of definite proportions.

But as the student will find in most books on this subject, that mixtures are distinguished from compounds only by the means necessary to separate their ingredients, we have thought best, at present, to continue the same division; at the same

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What bodies combine in limited proportions on one side, and unlimited proportions on the other? In what proportions do water and common salt combine? In cases where bodies unite in all proportions, is the force of affinity strong or weak? What are the substances mentioned which unite in all proportions? In what respect do combinations, formed by feeble affinities, resemble mixtures, and in what respect do they resemble chemical compounds? What are these slight combinations called in the Library of Useful Knowledge?

time, having it distinctly understood, that the universality of definite proportions, applies only to energetic combinations.

DEFINITE PROPORTIONS.

191. By *definite proportions* in chemistry, it is meant that the ingredients, or elements of chemical compounds, unite with each other in certain proportions only; and that these proportions in the same compound, are, under all circumstances, invariably the same. The proofs of this doctrine are established by experiments conducted with the most rigid exactness, and, it is true, beyond all controversy.

The subject of definite proportions may be conveniently treated of under three several propositions or laws, it being understood that the proportion of hydrogen in water represents unity, or 1, and that this is the common unit to which all the other numbers refer.

192. First. *The composition of all chemical compounds is fixed and invariable.*

Experiment shows, that some bodies combine in only one proportion. Thus, there is only one compound of zinc and oxygen, called the *oxide of zinc.* Other bodies combine in two proportions. Thus, there are two oxides of copper, one of which is composed by weight of 1 proportion of oxygen and 8 of copper, and the other, 2 of oxygen and 8 of copper. Other bodies, again, combine in three, four, five, or even six proportions; the latter being the greatest number of compounds known to have been formed by any two substances, within the limits of definite proportions.

193. CHANGE OF PROPORTION CHANGES THE COMPOUND.—The proportion of any given compound being invariably the same, it follows that its characteristic properties depend on these proportions, and that if these proportions are changed, the compound will contain new properties, and therefore a new substance is formed. As an example of the change produced on the compound, by a different proportion of one of its constituents, we will cite mercury and chlorine, (*see Chlorine.*) These two substances unite in two proportions, the first of which is

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What is meant by definite proportions in chemistry? What is the first law of definite proportions? What two substances combine only in one proportion? What two substances are mentioned which combine in two proportions, and what are these proportions? What number of compounds are known to be formed by two elements? The proportions of any chemical compound being definite, what would be the effect of changing these proportions? What example is given of the difference between compounds formed of one and two proportions of the same elements?

composed of mercury 100, and chlorine, 36. This forms the well known medicine called *calomel*, and is sometimes given in dozes of a tea-spoonful at a time, without injury. The other is composed of mercury 100, and chlorine 72, being one more proportion of chlorine than is contained in the calomel. But the two compounds in their sensible qualities are entirely different, the latter being one of the most active and fatal of poisons, and is known by the name of *corrosive sublimate.* Thus, two substances uniting in one proportion, form a compound which is comparatively inert, while in another proportion they form one of the most virulent poisons known. Nor is there any medium, or half-way union between these bodies; they combine in these two proportions or not at all. For, suppose 100 parts of mercury should be exposed to the action of 40 parts, by weight, of chlorine, then the mercury would combine with 36 parts of the gas, and no more, leaving the other 4 parts remaining untouched. And so, on the contrary, if 110 parts of the metal be exposed to the action of 36 parts of the gas, then the gas will combine with 100 parts of the mercury, while the 10 parts would remain uncombined.

In all energetic combinations the proportions of the combining substances are limited in the same manner, though the protions themselves are exceedingly various. Indeed, it appears that the law of limited proportions is as universal and as permanent as the law of gravitation itself, and that its doctrines, so far from being founded on the theoretical opinions of men, are in truth issued on a general, but more recently discovered law of nature.

194. Second. *When two substances unite in more than one proportion, the second or third proportions are multiples of the first, by a whole number.*

This very remarkable law applies in every case where bodies unite with each other in more than one definite proportion. The expression of the law simply means, that the first proportion in which two bodies unite, is in the lowest or smallest proportion in which the two constituents are capable of uniting with each other, and that the other proportions are double, triple, or quadruple, this lowest proportion.

What is said concerning the combination of mercury and chlorine in other proportions? Will 40 parts of chlorine unite with 200 parts of mercury? On what is it said the truth of the law of definite proportions is founded? What is the second law of definite proportions? What explanations are given of this law? Suppose the smallest proportion in which nitrogen and oxygen combine are fourteen of the first, and eight of the last by weight, what then will be the second proportion in which oxygen combines with nitrogen?

For example, the several compounds of nitrogen and oxygen are in the following proportions to each other, viz.:

		Nitrogen.			Oxygen.	
Nitrous oxide,	consists of	14	parts	and	8	parts.
Nitrous oxide,	"	14	"	"	16	"
Hyponitrous acid,	"	14	"	"	24	"
Nitrous acid,	"	14	"	"	32	"
Nitric acid,	"	14	"	"	40	"

Thus the lowest proportions in which oxygen and nitrogen combine, being to each other as the numbers 8 and 14, all the other proportions of oxygen are multiples of this first number, while the proportion of nitrogen remains the same. The second number is the first multiplied by 2; the third, the first multiplied by 3; and so on. These proportions are therefore to each other, as the numbers 1, 2, 3, 4, and 5.

Illustrations of this law can be observed throughout every department of chemistry, where the analysis of chemical compounds are given, and with a single exception, or two, where it is most probable the fault is either in the analysis or the want of knowledge, the same principle is found to be exactly true. One of these exceptions is found in an oxide of manganese, and will be pointed out hereafter.

195. MULTIPLE PROPORTIONS.—On these discoveries is founded the law called the *law of multiple proportions*, a phrase which is often repeated in all the late works on Chemistry, and of its general truth, as already observed, there can be doubt. In the above example, all the succeeding proportions of oxygen are multiples of the first.

196. Third. The third law of combination is nearly connected with the last, though the difference of expression and of meaning will be obvious. This law is not less extraordinary than that of multiple proportions, and may be understood by the following examples.

Water, we have already seen, is composed of 8 oxygen and 1 hydrogen; hyposulphurous acid is composed of 8 oxygen and 16 sulphur. Now, it is a curious fact, that the gas called sulphureted or sulphide of hydrogen, is constituted of 1 hydrogen

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What the third, what the fourth, and what the fifth? What is the third law of definite proportions? Explain this law. Suppose 64 represents the metal, and 8 the oxygen, in an oxide of copper, and suppose there is a second oxide, what would be the numbers representing the metal and the oxygen?

and 16 sulphur; that is, the quantities of hydrogen and of sulphur which combine with the same quantity of oxygen, combine with each other. Again, 36 parts of chlorine and 8 of oxygen constitute the oxide of chlorine, and with 1 of hydrogen, form muriatic acid gas: also, 16 parts of sulphur combine with 36 of chlorine to form the chloride of sulphur. Hence, bodies unite in proportional numbers, as in the above instances the proportion of *hydrogen* is 1, that of *oxygen* 8, that of *sulphur* 16, and that of *chlorine* 36.

But this law not only applies to the elementary parts of substances, such as hydrogen, oxygen, chlorine, and sulphur, but also to compound bodies, whose combining proportions may likewise be expressed by numbers.

197. Now, the proportions of any compound being expressed by the numbers attached to each element of which it is composed, the number representing the compounds is composed of the sum of its parts, or elements. Thus water is composed of oxygen 8, hydrogen being 1, and its combining proportion will therefore be $8+1=9$. When one element combines with another in several proportions, the number representing the single proportion, and those representing the several other proportions, are added together to make up the combining number of the compound. Thus, sulphuric acid is composed of one proportion of sulphur 16, and three proportions of oxygen; and as one proportion of oxygen is 8, so the whole number representing the oxygen in this acid is 24; to which 16 being added, makes the number representing sulphuric acid to be 40.

198. LEAST PROPORTION THE FIXED NUMBER.—It must be remembered that the smallest proportion, by weight, in which an element is found to combine, is the fixed number by which that element is always represented. Oxygen is invariably represented by 8, because this is the smallest proportion in which it is known to combine with any other substance. Thus, also, water is composed of oxygen 8, and hydrogen 1; potash of oxygen 8, and the metal, potassium 40. The lowest proportion in which sulphur is known to combine with any other

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Does this law of numbers apply to the elements of bodies only, or to the compounds also? When the numbers for the elements of a compound are known, how may the number for the compound be found? What are the numbers for hydrogen and oxygen in water? What then is the number for water? How does it appear that 40 is the number for sulphuric acid? Are the numbers for each element and compound invariable?

substance is 16, and therefore sulphur is always represented by this number. Thus sulphuret of lead is composed of one proportion of sulphur 16, and one of lead, whose combining number is 104. Its number therefore is $16+104=120$. We have just mentioned that the combining number of any compound is represented by the sum of its simple, or elementary parts. This will now be understood; for by adding the numbers representing the elements in each of the above examples, we shall have those by which the compounds are represented. The number for water, as already shown, is 9; the number for potash is 48, viz., 8 hydrogen, and 40 potassium; that for sulphuret of lead is 120, viz., sulphur 16, and lead 104.

199. By remembering the combining weights of the elements of any compound, the number representing that compound may at once be known. For example, *hydrate of potash* is composed of water and potash; water is composed of oxygen 8, and hydrogen $1=9$. Potash is composed of potassium 40, and oxygen $8=48$. These two sums being added, viz., $9+48=57$. Thus, the number for hydrate of potash is 57. Again, the salt called *sulphate of potash* is compounded of sulphuric acid and potash. Now, to find the number representing its combining proportion, we have only to remember that sulphuric acid is composed of one proportional of sulphur 16, and three proportionals of oxygen 24, and that the sums of these two numbers are 40. The number for potash, as above seen, is 48; therefore the number for sulphate of potash, being the sum of these two numbers, is $40+48=88$.

It is unnecessary to adduce further examples, since the intelligent student will be able to understand from the above epitome, not only on what kind of facts the laws of definite proportions are founded, but will also, it is hoped, be able to apply the above principles to the proportional numbers of the most common substances to be mentioned hereafter.

COMBINATION BY VOLUMES.

200. The doctrine of definite proportions was founded on the suggestions of Mr. Higgins, of Glasgow, published in 1789.

On what circumstances is the number for an element founded? What is the number for sulphuret of lead? What other numbers is this number composed of? Hydrate of potash is composed of water and potash, how will you find the number which represents hydrate of potash? What is the composition of sulphate of potash? How may the number representing this compound be found? Who first suggested the doctrine of definite proportions? Who extended this subject, and brought it before the public?

But it was Mr. Dalton, of Manchester, in England, who established the laws of chemical combinations, and who has the merit, of not only discovering almost all that is known in the details of this subject, but also of having brought it distinctly before the world. Mr. Dalton published his views of the doctrine of definite proportions in 1808, soon after which, Gay Lussac, a French chemist, proved, by a publication in one of the journals, that gases unite in simple and definite proportions, and among other instances, showed that water is composed precisely of 100 volumes of oxygen, and 200 volumes of hydrogen. It was afterward shown, by the same author, that other gaseous substances, which are capable of a chemical union with each other, unite in definite proportions, by measure or volume, and that these proportions are in the simple ratio of 1 to 1, 1 to 2, 1 to 3, and so on, as above stated.

These observations have since been confirmed by numerous experiments, instituted by the first chemists of the age, and at present it is as fully established, that the law of definite proportions extends to the volumes of gases, as it does to their weights, and to those of solids. As an illustration of the truth of this law, we adduce the condensation of hydrogen and oxygen by combustion, because these gases are more generally known than any others, and because their combination is also one of the most familiar examples of definite proportions by weight. The apparatus for this purpose it is unnecessary to describe, it being sufficient for our present purpose to state that the experiment has often been made with the most infallible accuracy.

201. METHOD OF FINDING PROPORTIONS.—The invariable proportions in which oxygen and hydrogen combine, are, by volume, one of the first, and two of the last, and by weight, sixteen of oxygen to one of hydrogen. Thus, the specific gravities of these two gases are to each other as the numbers one and sixteen, that is, a cubic foot of oxygen is just sixteen times as heavy as the same bulk of hydrogen. The reason why hydrogen is represented by one, as its combining proportion, by weight, while its combining volume is double that of the oxygen, will be seen hereafter. The mode of ascertaining the comparative volumes in which these two gases combine, is to

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What is said relative to the union of the gases by volume ? In what ratio do the gases combine by volume ? What illustration is given of the union of the gases by volume ? What are the proportions in which hydrogen and oxygen combine by volume, and what are these proportions by weight ? What are the relative specific gravities of these two gases ? What is the mode of ascertaining the volumes of these es ?

measure them carefully, and having introduced them into a glass tube, the mixture is inflamed by an electric spark; and in every instance it has been found, that whatever the proportions of the mixture might be, in respect to each other, the ratio of combination is always the same, and consists of two parts of hydrogen, and one of oxygen, by volume. When one measure of oxygen is mixed with three of hydrogen, there will remain in the vessel one measure of hydrogen uncombined and pure, and no continuance of the electricity will, in the least, change this proportion; and so, two measures of oxygen and two of hydrogen, leave one measure of oxygen in the same manner.

202. **Union by volume.**—When other gases unite, merely in consequence of being brought into contact, and without combustion, the same law applies; that is, if the volume of one be greater than its combining proportion, the excess remains pure and untouched.

We give a few examples of the proportions in which gases unite by volume:

Volumes.		Volumes.
100 muriatic acid gas	combine with	100 ammoniacal gas.
100 oxygen gas	"	200 hydrogen gas.
100 hydrogen gas	"	50 oxygen gas.
100 nitrogen gas	"	200 oxygen gas.
100 chlorine gas	"	100 hydrogen gas.
100 nitrogen gas	"	300 hydrogen gas.

Another curious fact concerning the union of the gases is, that many of them suffer a diminution of bulk, which is also in a simple ratio to the volume of the one or both. Thus, when three volumes of hydrogen and one of nitrogen combine, they instantly contract into two volumes, or one half their former bulk, and form gaseous ammonia. A similar condensation takes place when several of the other gases combine.

Suppose one measure of oxygen is mixed with three of hydrogen, and inflamed, what will become of the third measure of hydrogen? Does the same law apply when two gases combine without combustion? What illustrations are given of the combination of gases by volume? What is meant by chemical equivalents?

CHAPTER IX.

CHEMICAL EQUIVALENTS.

203. It was long since proved by Wenzel, a German chemist, that when two neutral salts decomposed each other, the resulting compounds are likewise neutral. That is, the acid of one will exactly neutralize the alkali of the other; and although two new salts are formed by this mutual decomposition, they will both, like the original compounds, be equally neutral. If one of the salts be in quantity too large for the combining proportions, then the excess of that salt will remain undecomposed in the solution, and only such a portion of it will be decomposed as is just sufficient to neutralize the constituents of the other salt.

204. Hence, *Chemical Equivalents are those definite proportions of one substance, which neutralize definite proportions of another substance.*

The truth of this law may be demonstrated by setting down the combining numbers of two salts, and the number representing the two new compounds, and then by exchanging the numbers representing the combining parts, the numbers for each compound will be found to represent the number for the new compound, and the combined numbers of the old and new compounds will be equal to each other. Thus, the number for sulphuric acid is 40, and the combining proportion of potash is 48, and therefore the number for *sulphate of potash* is 88. The combining proportion of nitric acid is 54, and that of baryta 78, and the sum of these two numbers is 132, which represents the *nitrate of baryta*. Now, when these two salts are mingled together in solution, both are decomposed; the 54 parts of nitric acid of the *nitrate of baryta* will saturate the 48 parts of potash of the *sulphate of potash*, making a new salt, *nitrate of potash*, whose combining number is 102. At the same time, the 40 parts of sulphuric acid of the *sulphate of potash* will combine with, and saturate, the 78 parts of the baryta of the *nitrate of baryta*, forming another new salt,

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How may it be proved that when two salts decompose each other, the acid of one exactly neutralizes the alkali of the other? What number represents nitrate of baryta? What number represents sulphate of potash? When these two salts decompose each other, what are the names of the new salts formed, and what is the number for each?

sulphate of baryta, whose number will therefore be 40 added to 78=118.

Now, it may be observed that the sums of the proportional numbers of the old and new compounds are equal, and the same, and therefore that there can be no excess in either of the alkalies or acids. This may be shown thus:

Sulphuric acid 40, and potash 48, form sulph. potash,	88
Nitric acid 54, and baryta 78, form nitrate baryta,	132
Sum of the old compound,	220
Sulph. acid 40, and baryta 78, form sulph. of baryta,	118
Nitric acid 54, and potash 48, form nitrate of potash,	102
Sum of the new compound,	220

205. UTILITY OF THESE LAWS.—The utility of being acquainted with these important laws is almost too manifest to require notice. Through their aid, and by remembering the proportional numbers of a few elementary substances, the composition of an extensive range of compound bodies may be calculated with facility. By knowing that 6 is the combining proportion of carbon, and 8 of oxygen, it is easy to recollect the composition of carbonic oxide, and carbonic acid; the first being composed of 6 carbon and 8 oxygen, and the second of 6 carbon and 16 oxygen. By simply remembering, therefore, that carbonic oxide is composed of one proportion of carbon, and one proportion of oxygen, and knowing that carbon is represented by 6 and oxygen by 8, we at once arrive at its composition. And by recollecting that carbonic acid has one proportion of carbon and two of oxygen, the composition of this is also known. It may be remembered that the number for potassium is 40, and that when combined with one proportion of oxygen 8, it forms potash 48. Now, by remembering these data, we know, without further trouble, the composition of the *carbonate* and *bicarbonate of potash*. The carbonate being composed of one proportion of carbonic acid, 22, (that is, 6 carbon and 16 oxygen,) and one proportion of

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What is the sum of the numbers of the old salts, and what the sum of the numbers of the two new salts? What is the equivalent number for carbon? What is the equivalent number for oxygen? Carbonic acid is composed of one equivalent of carbon, and two equivalents of oxygen, now what is the number for carbonic acid?

potash 48, (that is, potassium 40 and 8 oxygen,) is represented by 70. The bicarbonate is composed of one proportion of potash, 48, and two of carbonic acid, 44, and its number is, therefore, 92.

206. Again, having in the memory the numbers representing carbonic acid, we can readily apply them to the composition of other compounds, with which this acid is united. Thus, the number for *carbonate of soda* is 54, and we know from its name, (*see Nomenclature*,) that it contains only one proportion of carbonic acid. Now, by recollecting the combining proportion of sodium, we know, in a moment, the composition of the carbonate of soda. The combining number for carbonic acid being 22, this subtracted from 54, leaves 32 for the other combining proportion, and knowing that 24 is the number for sodium, and that soda is composed of sodium and oxygen, and that the combining number of oxygen is 8, we ascertain the composition of the salt in question, viz.: sodium 24, oxygen 8=32 soda; carbonic acid 22=54 carbonate of soda.

By the same law of proportions, suppose it is required to find the composition of *sulphate of soda*. The composition and number of soda being known, we have only to remember that the combining proportion of sulphur is 16, and that sulphuric acid is composed of one proportion of sulphur and 3 of oxygen, and the composition of this salt and its number is ascertained. Soda 32, sulphur 16; oxygen 3 proportions, 24, 16=40 added to 32=72. Therefore the number for sulphate of soda is 72, and its composition 32 of soda and 40 of sulphuric acid.

Thus by the application of this law to the combining numbers, or the equivalents of chemical bodies, the composition of most compounds may be readily ascertained.

METHOD OF ASCERTAINING THE EQUIVALENT NUMBERS OF COMPOUNDS.

207. The combining numbers of all the elementary bodies, as already stated, represent the smallest proportions in which they are severally found in union with any other body. But it is obvious that all these numbers must have one common unit from which they are calculated, otherwise there would exist no proportions between them. For this purpose, ***hydro-***

Why is the number, or equivalent, of carbonate of potash seventy? Why is bicarbonate of potash represented by ninety-two? Why is carbonate of soda represented by fifty-four? By the same law of proportion, show why the equivalent for sulphate of soda is seventy-two?

gen, as uniting in the lowest possible proportion, is employed. Thus, hydrogen unites with oxygen in one proportion, by weight, to form water, and the weight of hydrogen being 1, the weight of oxygen in water is 8, which is also the smallest proportion in which the latter body is found in union.

These two elements, having an extensive range of affinity, and therefore being found in combination with a great variety of other substances, are made the data, or points of comparison, from which all the other numbers are calculated.

Afterward, other compounds were examined which contained the smallest proportions of these elements united to other substances. Among these it was found that the gas called *carbonic oxide*, contained the smallest combining proportion of carbon, united with the smallest proportion of oxygen, these proportions being as 6 to 8. And also, that the gas called *sulphureted hydrogen*, contained the smallest proportion of hydrogen united to the smallest of sulphur, these proportions being 1 of hydrogen and 16 of sulphur.

Thus, the numbers for carbon and sulphur were found to be 6 for the former and 16 for the latter, the numbers for hydrogen and oxygen being 1 and 8.

On examination of the different oxides of iron, it was found that the least proportion with which that metal combined with oxygen, was that of 28 of the former, and 8 of the latter. The number for iron is therefore 28, and that of this oxide of iron 32.

In this manner the proportional numbers of each compound has been ascertained, and from these, tables of chemical equivalents have been constructed.

208. **Whole numbers.**—In the above epitome of the doctrine of chemical equivalents, we have adhered to the practice of giving whole numbers to the combining proportions, as being sufficiently near the truth for all common purposes, and by far less perplexing to the student than to add the decimal parts indicating the exact compositions.

209. In this edition the tables contain the fractional portions of the elements, but in some instances they are employed in round numbers, as being more within reach of the memory. The tables contain all the new metals, but it will be seen

What are the units, or data, from which the combining numbers, or equivalents, are calculated? Having the numbers for hydrogen and oxygen as data, how are the numbers for other bodies found? What are the equivalent numbers for carbon and sulphur? Explain how the number for iron was found that some are without equivalents, these having not yet been ascertained. The table is from Graham's last edition, London, 1853.

TABLE OF ELEMENTS, WITH THEIR EQUIVALENTS, HYDROGEN BEING 1.

	Names of elements.	Atomic numbers.
1.	Aluminum,	13.69
2.	Antimony, (Stilbium,)	129.03
3.	Aridium,	
4.	Arsenic,	75
5.	Barium,	68.64
6.	Bismuth,	70.95
7.	Boron,	10 90
8.	Bromine,	78.26
9.	*Cadmium*,	55.74
10.	Calcium,	20
11.	Carbon,	6
12.	*Cerium*,	46
13.	Chlorine,	35.50
14.	Chromium,	28.15
15.	Cobalt,	29.52
16.	Copper, (Cuprum,)	31.66
17.	Didymium,	
18.	Donarium,	
19.	Erbium,	
20.	Fluorine,	18.70
21.	Glucinum,	26.50
22.	Gold, (Aurum,)	98.34
23.	Hydrogen,	1
24.	Ilmerium,	
25.	Iodine,	126.36
26.	Iridium,	98.68
27.	Iron, (Ferrum,)	28
28.	Lanthanium,	48
29.	Lead, (Plumbum,)	103 56
30.	Lithium,	6.43
31.	Magnesium,	12.67
32.	Manganese,	27.67
33.	Mercury, (Hydrarygum,)	100.07
34.	Molybdenum,	47.88
35.	Nickel,	29.57
36.	*Niobium*,	
37.	*Norium*,	
38.	Nitrogen,	14
39.	Osmium,	99.56
40.	Oxygen,	8
41.	Palladium,	53.27
42.	*Pelopium*,	
43.	Phosphorus,	32
44.	Platinum,	98.68
45.	Potassium, (Kalium,)	39
46.	Rhodium,	52.11
47.	Selenium,	37.57
48.	Silicon,	21.35
49.	Silver, (Argentum,)	108
50.	Soda, (Natron,)	22.97
51.	Strontium,	43.84
52.	Sulphur,	16
53.	*Tantalum*, (Columbium,)	92.30
54.	*Tellurium*,	66.14
55.	*Terbium*,	
56.	*Thorinum*,	59.67
57.	Tin, (Stannum,)	58.82
58.	Titanium,	24.29
59.	Tungsten, (Wolfram,)	94.68
60.	*Uranium*,	60
61.	*Vanadium*,	68.85
62.	Yttrium,	32.20
63.	Zinc,	32.50
64.	Zirconium,	33.62

NOTE.—The words in brackets are the Latin names of such elements as are indicated by corresponding symbols, as Na, for Natron, Soda.

EXPLANATION.—In a considerable number of instances, the combining numbers have been changed since our last edition. Where the old numbers have been used in the text, we have endeavored in this edition to change them for the new ones, but, perhaps, have not always done so. At any rate, the true numbers are contained in the above table.

210. **ONLY SIXTY-FOUR KNOWN ELEMENTS.**—Every substance upon our globe, so far as is yet known, is composed of one or more of the simple bodies contained in the above catalogue. Some of them, as vanadium, and uranium, are of very rare occurrence, while others, as aluminum, iron, and calcium, are very abundant in nature, though combined with other substances. It will be observed that by far the greatest number of them comes under the denomination of metals, though several of these, as potassium, calcium, and sodium, can not be obtained in a separate state, without the most refined and powerful chemical aid. Among them all, the most common and abundant in nature are oxygen, hydrogen, carbon, and nitrogen, as it will be remembered, that of these elements are composed, water, air, vegetable, and animal substances.

211. **CLASSIFICATION OF THE METALS.**—The metals have been the subjects of various classifications by different writers. When we come to treat of them separately, we shall give a more practical division. In the following table they are arranged according to their affinity for oxygen:

I.

Potassium,
Sodium,
Lithium,
Calcium,
Barium,
Strontium,
Magnesium.

II.

Manganese,
Iron,
Zinc,
Tin,
Cadmium,
Cobalt,
Nickel.

III.

Copper,
Lead,
Antimony,
Bismuth,
Uranium,
Titanium,
Cerium,
Tellurium.

IV.

Arsenic,
Molybdenum,
Chromium,
Vanadium,
Tungsten,
Columbium.

V.

Mercury,
Silver,
Gold,
Platinum,
Palladium,
Rhodium,
Osmium,
Iridium.

VI.

Glucinum,
Zirconium,
Yttrium,
Thorinum,
Aluminum,
Silicium.

VII.

Erbium,
Terbium,
Didymium,
Niobium,
Ruthenium,
Pelopium,
Donarium.

NOTE.—The last group, vii., are chiefly new metals, the places of which, in the above arrangement, are unknown; we have, therefore, thrown them together, and shall hereafter give such an account of each as the most recent publications contain.

What are the names of the new metals?

WOLLASTON'S SCALE OF CHEMICAL EQUIVALENTS.

212. Dr. Ure says, that this scale of chemical equivalents has contributed more to facilitate the general study and practice of chemistry than any other invention of man. It consists of a piece of mahogany board two or three inches wide, and of a length proportionate to the extent of the scale it contains, or of the size of the type in which it is printed. Running through the middle of the board there is a sliding rule containing the proportionate numbers of all the most common chemical compounds, and on each side of the rule are printed the names of the compounds corresponding with these numbers. The divisions of this scale are laid out logometrically, after the manner of the common Gunter's scale, and consequently the ratios between the numbers are found by the juxtaposition of the several lines on the sliding and fixed parts with the greatest accuracy.

The arrangement of this instrument is such, that the weight of any ingredient in a compound, or its definite proportion, and also the equivalents of the acids and alkalies, may be at once seen by merely moving the sliding part.

213. On this scale, instead of taking hydrogen for unity, Dr. Wollaston has taken oxygen, which he calls 10; but if we slide down the middle rule so that 10 on it stands opposite to 10 hydrogen on the left hand, then every thing on the scale will be in accordance with Sir H. Davy's system of proportions, taking hydrogen for unity, and also in accordance with the theory of definite gaseous combination by volume.

The principle on which this instrument works may be learned in a few minutes; and after a little practice, it becomes one of the most efficient and beautiful of labor-saving machines, to both the practical and theoretical chemist.

Nothing but actual practice with the instrument will convey to the mind of the learner a knowledge of its practical usefulness; we will however give an example, by which the principle of its construction may perhaps be comprehended.

214. We have already stated, that on this scale oxygen is the unit from which all the other proportions are calculated, and that this element is marked 10. When, therefore, 10 on the sliding rule is against this number, the weights of the other

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Describe the construction of Wollaston's scale of chemical equivalents? What principle does Dr. Wollaston call unity, and what is its number on the scale of chemical equivalents? On what evidence is the truth of the doctrine of definite proportions founded?

bodies are in due proportion to this number. Thus, carbonic acid being 27.54, and lime 35.46, carbonate of lime being the sum of these numbers, is placed at 62. Then, if the sliding rule be drawn upward, so that the number 100, on it, corresponds with carbonate of lime, the other number will correspond with carbonic acid and lime, and will show the proportions in which these ingredients unite to form 100 parts of carbonate of lime. Thus, the number 56 corresponds with lime, while 44 corresponds with carbonic acid, these two numbers making 100.

THEORY OF ATOMS.

215. To be decided by experiment only.—That chemical bodies unite in definite proportions, by weight, and also by volume, and that where one body unites with another in more than one proportion, the second is a multiple of the first, are facts resting on the evidence of experiment alone. These facts, in themselves so wonderful, and in their relation to science so important, excited the inquiry and speculations of many philosophic minds, as to their cause. Among these inquirers, Mr. Dalton, of Manchester, seems to have been the most successful, having proposed a theory which accounts, with few, if any exceptions, for all the phenomena observed, and which, therefore, explains satisfactorily the reasons why bodies combine in such proportions. As the basis of this theory, Mr. Dalton assumes that the union of bodies in their smallest proportions, always takes place between the atoms of which they are composed; that is, one atom of one body combines with one atom of the other body. Thus, water is formed by the combination of one atom or particle of oxygen combined with one particle or atom of hydrogen. This theory supposes also that the ultimate atoms of matter are indivisible; that they are always of the same shape and size in the same body, and that their weights are different in the different bodies. Thus, the weight of an atom of oxygen is 8 times that of an atom of hydrogen, these being the proportions in which these gases form water. But when bodies unite in several proportions, then it is 2 or 3 atoms of one, to one atom of the other. Thus sulphurous acid

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What is said of Mr. Dalton's theory of atoms? What does Mr. Dalton assume as the basis of his theory of atoms? On this theory what is water composed of? What does this theory suppose, in respect to the divisibility, shape, and weight, of the atoms of bodies? Why is an atom of oxygen supposed to be eight times as heavy as one of hydrogen? Why is an atom of sulphur supposed to be twice as heavy as one of oxygen?

is composed of 2 atoms of oxygen united to 1 atom of sulphur, and sulphuric acid is composed of 1 atom of sulphur and 3 atoms of oxygen, these being the relative weights of their elements. But as it is found that the lowest proportion in which sulphur unites with any other body, it is in the proportion of 16 by weight, hydrogen being 1, so it is assumed that a particle of sulphur is sixteen times as heavy as one of hydrogen, and twice as heavy as one of oxygen. And as in sulphurous acid the weight of oxygen is found to be exactly double that in water, it is reasonable to suppose that sulphurous acid consists of 1 atom of sulphur united to 2 atoms of oxygen, and for the same reason, since sulphuric acid contains three times the weight of oxygen that water does, that this acid is composed of 1 atom of sulphur and 3 atoms of oxygen.

216. WHY BODIES UNITE IN DEFINITE PROPORTIONS.—All this, whether true or false, explains in the most satisfactory manner, why bodies combine with each other in definite proportions, and why these proportions are expressed by the numbers attached to each. Thus, hydrogen is unity, or the prime equivalent, and is expressed by 1, because by weight this gas is found to form water by uniting with 8 parts of oxygen. Oxygen is expressed by 8, because its proportion in water weighs eight times as much as the hydrogen. The number for sulphur is 16, because this is the smallest proportion in which it unites with any substance, and the number for the oxygen in sulphurous acid is 16, because in this acid the sulphur and oxygen are of equal weights, and therefore just twice the weight of the oxygen in water; and the number for the oxygen in sulphuric acid is 24, because its weight is three times that in water.

Now, by supposing that one atom of oxygen is eight times as heavy as one of hydrogen, and that an atom of sulphur is twice as heavy as one of oxygen, or sixteen times as heavy as one of hydrogen, the whole mystery of the law of definite proportions is reduced to simple arithmetical calculation, for the proportional numbers are in fact nothing more than the relative weights of the atoms of which the several bodies are composed.

Why is it supposed that sulphurous acid contains one atom of sulphur united to two atoms of oxygen? That sulphuric acid is composed of one atom of sulphur and three atoms of oxygen? Why is the equivalent number of oxygen eight? Why is that for sulphur sixteen? Why is the number for oxygen in sulphuric acid twenty-four? What is said of the proportionate numbers in relation to the weights of the atoms of bodies?

217. **Atomic theory not proved.**—In respect to the truth or falsity of this theory, it is obviously without the bounds of demonstration, for we never can ascertain whether the proportions on which it is founded are the smallest in which bodies combine, nor whether, if so, they combine atom to atom, as is supposed. But whether it be true or false, it does not in the least affect the truth of the law of definite proportions, which, as already stated, is founded on experiment alone, and is, therefore, purely an expression of facts. The atomic theory, however, must always be considered an elegant and probable hypothesis; and, while it displays uncommon ingenuity, and great chemical research, has the advantage of agreeing, in general, perfectly with the facts obtained by analysis.

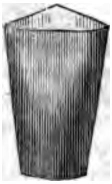
CHAPTER X

CHEMICAL APPARATUS.

218. Before proceeding to treat of *ponderable bodies*, and the description of particular agents, it is proposed to describe some of the most common and necessary utensils, used in the manipulations of chemistry.

219. A **crucible**, Fig. 47, is a deep conical cup, of a triangular shape at the top, and round at the bottom. Crucibles are made of this shape for the convenience of pouring out their fluid contents at either angle. They are made of clay and sand baked hard, and will withstand very high degrees of heat without melting, but are liable to crack when suddenly cooled. They are chiefly manufactured at Hesse, in Germany, and hence are called *Hessian* crucibles.

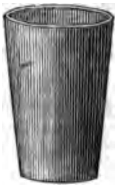
FIG. 47.



Crucible.

220. A **melting pot**, Fig. 48. These pots are made of various sizes and materials. Those used in large glass-houses are made of clay, and are of a large size. Chemists employ those made of silver or platina, as well as of black

FIG. 48.

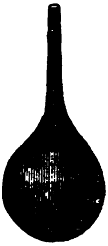


Melting Pot.

What is said in respect to the truth of this theory? Whether it is true or false, does it in the least affect the truth of the doctrine of definite and multiple proportions? What is a crucible, and for what purpose is it used?

lead, but of small dimensions. Metallic crucibles are used for particular purposes, when the substance to be experimented on would destroy the common crucible, in consequence of its corrosive quality.

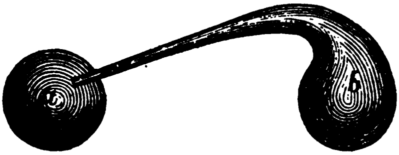
FIG. 49.



Matrass

221. A MATRASS, Fig. 49, is a glass vessel, in the shape of an egg, with a long neck. It is employed in effecting the solution of such substances as require heat, and long-continued digestion, for that purpose. When used, they are commonly placed in a *sand bath*, that is, in sand moderately heated.

FIG. 50.



Retort and Receiver.

222. A RETORT AND RECEIVER, Fig. 50. Retorts, *b*, are egg-shaped vessels, with the neck turned on one side. These vessels are of various capacities, from a gill to a barrel, or more. They are made of glass, metal, or earthen-ware, but most commonly of glass. No vessel is so much used in experimental chemistry as the retort. In the process of distillation, in collecting the gases, in concentrating the acids, and in a great variety of other operations, this vessel is universally employed.

The receiver, *a*, is a necessary appendage to the retort, and is destined to receive whatever comes over from it, during the process of distillation. For common purposes, these vessels are made of glass, but in the manufacture of various articles they are made of clay or metal.

223. A TUBULATED RETORT, Fig. 51. It differs from the plain retort, figured above, in having a *tubulure*, or opening, as seen in the figure, to which is fitted a glass ground stopper. This opening saves the trouble of detaching the retort from the

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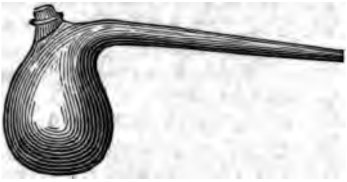
Of what are crucibles made? How do melting pots differ from crucibles? Of what substances are melting pots made? Of what are matrasses made? For what purpose are these vessels used? What is a retort? How large are retorts? Of what are retorts made? What are the uses of retorts? What is a receiver, and what is its use? Of what are receivers made? How does a tubulated, differ from a plain retort?

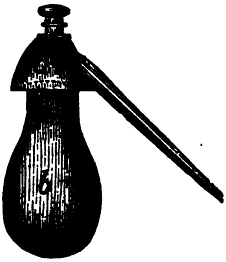
FIG. 51.



Tubulated Retort.

receiver when any additions are to be made to its contents, after they are connected, as in Fig. 50. It is also necessary for the introduction of a *safety tube*, a part of this apparatus absolutely necessary in some processes, and which will be described in another plate.

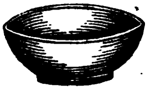
FIG. 52.



Alembic.

224. An ALEMBIC, Fig. 52, is used for the distillation or *sublimation* of solid, volatile substances. It consists of two parts, the head, *a*, which is ground on, so as to be perfectly tight, and the body, *b*, which is set into a sand bath, when in use. The product of sublimation rises into the head, where it is condensed, and then runs down the spout into a receiver.

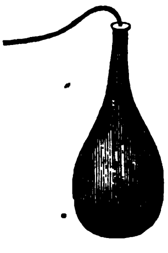
FIG. 53.



Evaporating Dish.

225. EVAPORATING DISH, Fig. 53. Every chemical apparatus must have among its utensils shallow dishes for evaporating fluids. The best are made of Wedgewood's ware, and come packed in nests containing several sizes each. The heat is applied by means of heated sand or ashes; and these vessels are used to evaporate solutions of salts, in order to obtain crystals, and for various other purposes.

FIG. 54.



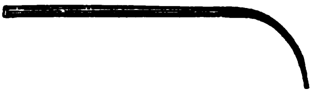
Florence Flask.

226. A FLORENCE FLASK, Fig. 54, furnished with a tube, to be used instead of a retort. Students will save considerable expense by employing these flasks in the room of retorts. The cork is pierced with a burning iron, and through the aperture is passed a tube of glass or lead, bent as in the figure. In obtaining oxygen, by means of oxide of manganese and sulphuric acid, and for many other purposes, this arrange-

What is the use of the tubulure, or opening, in this retort? What is an alembic? What is the use of the alembic? Of how many parts does the alembic consist?

ment will serve instead of the best retort, while, if broken, the expense is only a few cents.

FIG. 55.

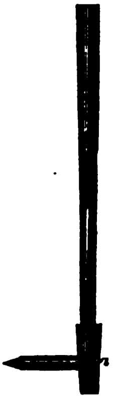


The Common Blow-pipe.

227. The COMMON BLOW-PIPE, Fig. 55, is a little instrument by means of which the most violent heat of a furnace may be produced. It is a pipe of brass, about the third of an inch in diameter at the largest end, and thence tapering, gradually, to a point, and bent, as in the figure.

To use it, place the curved end in the flame of a lamp, or candle, and apply the lips to the other end, then blow gently and steadily, giving the jet of flame a horizontal direction. To keep up a constant stream of air for a length of time, the inspiration must be made by the nostrils, while the cheeks are used as bellows. The art of doing this is soon learned by practice. The small fragments of ore, or other substance, on which the flame is thrown, must be laid on a piece of charcoal, which is held by small forceps. When a very intense heat is required, and the fragment is so light as to be blown away by the air, it may be confined by making a small cavity in the charcoal support, into which the substance is put, and another piece of charcoal is placed partly over this.

FIG. 56.



Gahn's Blow-pipe.

228. GAHN'S BLOW-PIPE, Fig. 56, is a much more convenient form than the common one above described. In the common form, the flame is sometimes nearly extinguished, and the process stopped, by the condensed moisture from the breath. In Gahn's instrument this is prevented by the chamber *a*, which retains the condensed moisture, and which may be taken off from the main pipe for its removal. The tip of the small pipe through which the air passes to the flame, fits to a socket, so that those of different sized orifices can be used.

229. DROPPING TUBE, Fig. 57, is a small glass tube, blown into a ball in the middle, and ending

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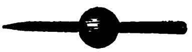
For what purposes are evaporating dishes employed? What does Fig. 54 represent? What are the advantages of using Florence flasks instead of retorts? What is the common blow-pipe? What is the use of this instrument? Describe the mode of using it. How does Gahn's blow-pipe differ from the common one? What are the peculiar advantages of this blow-pipe?

FIG. 57.



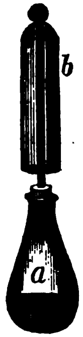
Dropping Tube.

with a fine orifice at the lower end. It is filled by dipping the small end into the fluid, and exhausting the air by sucking at the upper end with the mouth. The thumb is then placed on the upper end, which keeps the liquid from running out. On raising the thumb, the contents will descend in drops, but is instantly restrained on replacing it.

This little instrument is highly useful for various purposes, and particularly when it is required to introduce one fluid under another, as water under alcohol, or sulphuric acid under water.

230. **Ammonia apparatus.**—Fig. 58 is designed to collect and retain, for the purpose of temporary examination, such gases as are lighter than the atmosphere, and at the same time are absorbable by water. These gases, for more thorough examination, require the aid of a mercurial bath, but most of their properties may be examined by the apparatus represented by the figure.

FIG. 58.



Ammonia Apparatus.

The flask, *a*, is to contain the materials for extricating the gas, and into the mouth of this there is inserted a tube a foot or more long. The tall bell glass, *b*, or a large tube closed at the upper end, is inverted over this tube, as seen in the figure.

As an example of the use of this apparatus, suppose we desire to make some experiments on *ammonia*, a gas which is rapidly absorbed by water and specifically lighter than atmospheric air. The materials for separating this gas are *muriate of ammonia*, called also *sal ammoniac*, and slaked *quicklime*. These being separately reduced to powder, equal parts are then mixed, and introduced into the flask *a*, and the tube put into its place. On application of a gentle heat, the gas will be set free in consequence of the combination which takes place between the lime and the muriatic acid of the muriate of ammonia. The ammonia is thus set at liberty, and being lighter than the air, ascends and gradually

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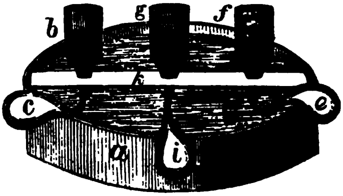
Describe the construction of Gahn's blow-pipe. What is the shape of the dropping tube? What is the use of this instrument? Describe the manner of using the dropping tube. For what purposes is the dropping tube useful? What is the use of the apparatus represented in Fig. 58? Describe Fig. 58, and explain an example of its use. How may ammonia be obtained and examined by means of this apparatus? What is represented by Fig. 59? Why can not the gas be poured from one vessel to another, and be retained in an open vessel like water?

displaces the air from the vessel *b*, and takes its place. This experiment affords an instance of the chemical action of two solids on each other.

231. GAS APPARATUS.—Fig. 59 is designed as a simple illustration of a *gas apparatus*. The method of making experiments with the permanently elastic fluids, such as common air, and the gases, and of transferring them from one vessel to another, though sufficiently simple, requires some directions for the new beginner. The gases are none of them sufficiently dense to be retained in vessels open to the air for any considerable time; and some of them being lighter than the atmosphere, instantly ascend, and are lost, when the vessels containing them are opened. All the gases, therefore, when open to the air, mix with it more or less rapidly, according to their densities, and thus escape us entirely, being diffused in the atmosphere. Hence, to retain a gas in a state of purity, it must be kept from contact with the atmosphere, and hence, also, the necessity of first filling the vessel with a fluid instead of air, before the gas is introduced, and of transferring it under a fluid from one vessel to another.

FIG. 59.



Gas Apparatus.

The figure represents a wooden vessel, or tub, *a*, with a shelf, *k*, fixed a few inches from the brim. When the apparatus is to be used, the tub is to be filled with water, so as to rise a few inches above the shelf. Now, when a glass jar, or any other vessel, open only at one end, is filled with water, by being plunged into the fluid, it will retain its contents when raised above the fluid, provided its mouth be kept under it; for the water is sustained in the vessel by the pressure of the atmosphere, on the same principle that the mercury is sustained in the barometer tube. (*See Barometer in Natural Philosophy.*) The vessels *b*, *g*, *f*, represent jars filled with water, and inverted on the shelf, their necks passing through an aperture

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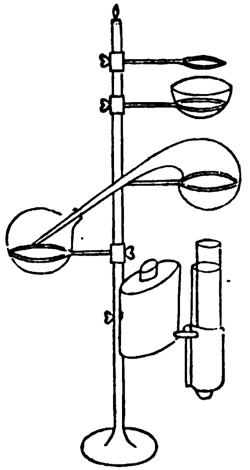
Explain the reason why a vessel filled with water may be raised above the fluid, provided its mouth be kept under it. When a tumbler is forced into the water with its mouth downward, why does not the fluid rise in it? When air is introduced under a vessel, inverted and filled with water, why does it rise to the highest part of the vessel?

in it, so as to preserve their upright positions. The vessels *e*, *c*, and *i*, are retorts, with their necks inserted into the mouths of the inverted jars.

232. Now, when common air, or any gas, is introduced into the mouth of a vessel so inverted, the air will rise to the upper part of the vessel, and will displace the water, and occupy its place. If a tumbler, or cup, in the state which we usually call empty, but which is really full of air, be plunged into water with its mouth downward, very little water will enter it, because the admission of the fluid is opposed by the included air; but if the mouth of the vessel be turned upward, it immediately fills with water, while the air is displaced, and rises to the surface of the fluid in one or more bubbles. Suppose this is done under the mouth of a jar filled with water, the air will ascend as before, but instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, air may be transferred from one vessel into another, by an inverted pouring, and the first portions, instead of occupying the bottom of the vessels, like water, ascend to the top, the air, instead of running from a higher to a lower vessel, rising from the lower to the higher one. This is owing to the pressure of the water on the air, or to the lightness of air when compared with water. For the same reason, lead being lighter than quicksilver, if a bullet of the former be sunk in a vessel of the latter, it will rise to the surface. On this principle balloons ascend; the hydrogen with which they are charged being thirteen times lighter than the atmosphere, the former is forced upward by the pressure of the latter.

FIG. 60.



Lamp Furnace.

233. A LAMP FURNACE.—Fig. 60 is one of the most indispensable articles in a chemical apparatus. It consists of a rod of brass, or iron, about half an inch in diame-

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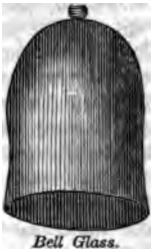
How does the rise of a balloon illustrate this principle? Describe the lamp furnace, Fig. 60. What are the uses of the rings on the ends of the arms?

ter, and three or four feet long, screwed to a foot of the same metal, or to a heavy piece of wood. On this rod, slide three or four metallic sockets, into which are screwed straight arms terminated with brass or iron rings of different diameters. The screws cut on the ends of the arms where they enter the sockets are all of the same size, so that the rings may be changed from one socket to another, as convenience requires. These rings are for the support of retorts, receivers, evaporating dishes, &c., as represented in the figure, and may be moved up, or down, or turned aside, and then fixed in their places, by means of thumb screws passing through the sockets and acting on the rod. The lamp by which the heat is given for distillation, or other purposes is also fixed with a thumb screw, so that the heat can be regulated by moving it up or down.

234. A BELL GLASS, Fig. 61, is employed in making experiments on air, or the gases. It is a glass vessel, of the shape represented in the figure, and of various sizes, from the capacity of a pint to that of several gallons. The knob at the upper part, is the handle by which it is moved. It is used for the temporary confinement of elastic fluids, on which experiments are to be made. Large tumblers are good substitutes for bell glasses.

FIG. 61.



Bell Glass.

CHAPTER XI.

SPECIFIC GRAVITY.

235. THE specific gravity of a body is its relative weight when compared with the same bulk of another body. For solids and liquids, water is the substance to which the weights of other bodies are compared; and for elastic fluids, the atmosphere is the standard of comparison.

When a body weighs twice as much as the same bulk of water, it is said to have the specific gravity of 2; and if it weighs three, four, or five times as much as the same bulk of water, it has the specific gravity of 3, 4, or 5. Water, therefore, is the unit, or standard of comparison, and has in this respect the specific gravity of 1.

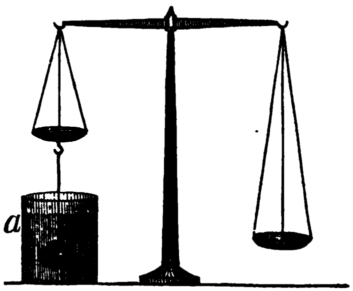
What are the uses of the thumb screws with which the sockets and lamp are furnished? What does Fig. 61 represent? What is the use of the bell glass receiver?

When a body is weighed in water, its weight will be diminished by exactly the weight of a quantity of water equal to its own bulk, and thus the difference between its weight in air and in water being known, its specific gravity is readily found.

Taking the specific gravities of bodies is a work of considerable delicacy, and requires some practice before it can be done in a manner to be depended upon. The experimenter should always have his pencil and paper in hand, in order to set down the relative weights as they are taken.

236. **Scales for specific gravity.**—In this edition we have added scales for the purpose of taking the specific densities of solids, being in some respects, a more simple method than by the balance, and besides requiring no other instrument than is in general use for other purposes.

FIG. 62.



Scales for Specific Gravity.

How to take the density. — First weigh the body in the usual manner, and note down the number of grains; then with a fine thread, suspend it from the bottom of the scale-dish, as shown by Fig. 62, in the vessel of water, *a*. As it will weigh less in water, add weights until the scale beam becomes horizontal; then note down the number of grains so added, and they will show the difference between the weight of the body in air and in water.

Rule.—*Divide the weight in air, by the loss in water, and the quotient will be the specific density.*

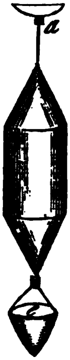
Illustrations and examples will be seen under the next article, where it will be observed that, although the means employed are quite different, the results are exactly the same.

237. **Portable balance.**—Another mode of taking the specific gravity of a solid, is by means of *Nicholson's Portable*

What is the specific gravity of a body? With what substances are solids and liquids compared to find their specific gravities? What is the standard of comparison for elastic fluids? Suppose a body weighs twice as much as the same bulk of water, what is its specific gravity? What does Fig. 63 represent? Describe this balance. What preparation is necessary before the balance is used? What are the balance weights? After the balance weight is known, how will you proceed to find the specific gravity of a body?

Balance, represented by Fig. 63. The body is a hollow cylinder of tinned iron, terminated at each end by a cone. From the vertex of the upper cone rises the small stem, *a*, of copper or brass, bearing a small tin cup. This cup slips on, and may be removed when the instrument is not in use. From the point of the lower cone is suspended the tin cup, *e*, at the bottom of which is attached a cone of lead so heavy as to sink the whole instrument in water nearly to the base of the upper cone. Before this balance is used, it is placed in a vessel of water, and the upper cup loaded with weights until it sinks so far that a mark on the stem at *a*, coincides exactly with the surface of the water. The weights, so added, are called the *balance weights*, and their amount may be marked on the cup as a given quantity for future use; suppose this is 900 grains.

Fig. 63.



Portable Balance.

238. The specific gravity of a solid may then be taken as follows: First place it in the upper cup, and add weights until the mark on the stem coincides with the water; suppose this to be 400 grains; subtract this from the balance weight, and we have 500 grains for its weight in air. Then remove the subject of experiment to the lower cup, and the stem will rise above the mark, because it weighs less in water than in air; weights must, therefore, be placed in the upper cup until the mark again coincides with the surface of the water; suppose this to be 100 grains, which will be exactly the weight of the water displaced by the mineral, or other solid. The specific gravity is now found by a very simple rule, already given.

In the present instance, we have 500 grains for the weight in air, and 100 for the loss in water; therefore, 100 : : 500=5, the specific gravity.

TABLE OF SPECIFIC WEIGHTS OF VARIOUS SOLIDS.

(FROM MULLER'S PHYSICS.)

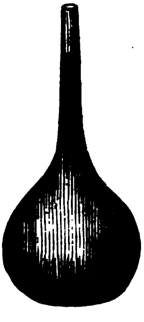
Platinum, coined, .	22.100	Gold, coined, . . .	19.325
" rolled, . .	22.069	" fused, . . .	19,258
" fused, . .	20.859	Copper, malleable, .	8.878
" wire, . .	19.267	" fused, . .	7.788

After finding the weight of a body in air, and its weight in water, what is the rule for finding its specific gravity? What are the most simple means of finding the specific gravity of a liquid?

Copper, wire, . . .	8.780	Iodine, ...	4.948
Cadmium, ...	8.694	Sulphate barytes, .	4.426
Molybdenum, . . .	8.611	Selenium, ...	4.320
Brass, ...	8.395	Flint glass, French, .	3.200
Arsenic, ...	8.308	" " English, .	3.373
Nickel, ...	8.279	Marble, ...	2.837
Uranium, ...	8.100	Emerald, ...	2.775
Steel, ...	7.816	Rock Crystal, . . .	2.683
Cobalt, ...	7.812	Porcelain, ...	2.493
Iron, wrought, . .	7.788	"	2.145
" cast, ...	7.208	Sulphur, native, . .	2.033
Tin, ...	7.291	Ivory, ...	1.917
Antimony, ...	6.712	Alabaster, ...	1.847
Tellurium, ...	6.115	Anthracite, . . .	1.800
Chromium, . . .	5.900	Phosphorus, . . .	1.770

239. SPECIFIC GRAVITY OF LIQUIDS.—The most simple method of taking the specific gravity of liquids, is by means of a graduated bottle holding 1000 grains of water, which is taken as the unit, or standard, for other liquids.

FIG. 64.



Density of Fluids.

Take a small bottle with a long narrow neck, as represented by Fig. 64, and having weighed it accurately, introduce into it exactly 1000 grains of pure water, and mark the level of the water with a file on the neck of the bottle. The bottle thus prepared will serve to ascertain the specific gravity of any fluid, for since water is the standard by which the comparative weights of all other fluids are known, the same bulk of any other fluid, weighed at the same temperature, will be its specific gravity.

Thus, suppose that when the bottle is filled with sulphuric acid up to the mark at which the water weighed 1000 grains, it should be found to weigh 1800 grains; then the specific gravity of the acid would be 1800, water being 1000. If filled to the same mark with alcohol, it might weigh 800 grains. The specific gravity of alcohol would therefore be 800, water being 1000. But as it is understood that

How does a bottle, filled with 1000 grains of water, become the standard for other liquids? Suppose a given bulk of water weighs 1000 grains, and the same bulk of another fluid 1600 grains, what would be the specific gravity of the latter?

water is the standard of comparison, the specific gravities of bodies are expressed merely by the numbers signifying their relation to this standard. Thus, the specific gravity of lead is 11, that is, it is 11 times as heavy as water, bulk for bulk; while the specific gravity of ether is 750, that is, a given bulk of ether will weigh 750 grains, ounces, or pounds, while the same bulk of water weighs 1000 grains, ounces, or pounds. (*See Specific Gravity in Natural Philosophy.*)

DENSITY OF SOME LIQUIDS AT 32 DEGREES FAHRENHEIT.

Distilled water, . .	1.000	Sulphuric acid, . .	1.848
Mercury, ...	13.598	" diluted, . .	1.215
Milk, ...	1.030	Sea water, ...	1.026
Oil, linseed, . . .	0.953	"	1.060
" poppy, . . .	0.929	Alcohol, absolute, .	0.793
" olive, ...	0.915	Sulphuret of carbon,	1.272
" turpentine, . .	0.872	Sulphuric ether, . .	0.716

240. SPECIFIC GRAVITY OF GASES.—To determine accurately the specific gravity of the gases, is an operation of great delicacy, and requires not only very nice apparatus, but much experience. The method by which it is done is, however, easily explained, and will be readily understood.

We have already said that atmospheric air is the standard of comparison for the gases. In the first place, therefore, it is necessary to ascertain the weight of a given volume of air. This is done by weighing, very accurately, a light glass vessel furnished with a good stop-cock, when full of air, or in its ordinary state. Then, having withdrawn the air by means of an air-pump, and closed the stop-cock, the vessel is again weighed, and the difference will show the weight of air which the vessel contained. On making this experiment, it is found that 100 cubic inches of air weigh 30.5 grains, and by the same method, the weight of a given portion of any elastic fluid may be ascertained. In all these experiments, it is understood that the thermometer stands at 60 degrees, and the barometer at 30 degrees.

Suppose, then, that the glass globe, *a*, Fig. 65, is of sufficient capacity to contain 100 cubic inches of air weighing 30.5 grains, and it is found, on filling it with oxygen, that the same quan-

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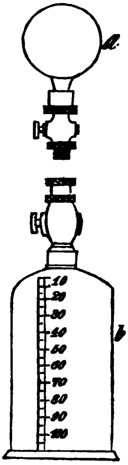
How is the specific gravity of a gas ascertained? What is the weight of 100 cubic inches of common air? Suppose it is found that 100 cubic inches of oxygen gas weighs 34 grains, how is its specific gravity found?

tity of this gas weighs 34 grains. Then to find the specific gravity of the latter gas we say, "*as the weight of the air is to that of the oxygen, so is unity, or the specific gravity of the atmosphere to the specific gravity of oxygen.*" Thus, 30.5 : 34 :: 1=1.1147, gives 1.1147 for the specific gravity of oxygen gas.

But since it is inconvenient in practice to experiment on just 100 cubic inches of gas, the graduated vessel, *b*, has been invented, to show at once what quantity of gas in cubic inches is weighed in the globe, *a*.

The globe being first exhausted of air, and its stop-cock closed, is then connected with the receiver, *b*, containing the gas, and both cocks being opened, the gas passes from the receiver to the globe. The receiver being open at the bottom, and set over water, or mercury, the rise of the fluid will show the quantity of gas which passes into the globe, and on weighing the globe, both before and after connecting it with the receiver, the difference will show the weight of the air thus transferred.

FIG. 65.



Graduated Jar.

DENSITY OF SOME OF THE GASES.

Atmospheric air,	1.000	Chlorine,	2.500
Carbonic acid,	1.527	Ammonia,	0.590
Carbonic oxide,	0.972	Cyanogen,	1.805
Hydrogen,	0.069	Nitrous oxide,	1.527
Nitrogen,	0.972	Oxygen,	1.111
Sulphurous gas,	2.222	Sulphureted hydrogen,	1.180

NOTE.—It will be observed in the above table, that instead of making the weight of 100 cubic inches of atmospheric air the standard of comparison, air is taken at 1,000, (in the same manner as water is for solids,) and with this as a unit, the other elastic fluids are compared. This is, no doubt, for common purposes, the easiest and best way.

Explain Fig. 65, and show the design of each vessel, and the manner of using them.

CHAPTER XII.

NOMENCLATURE.

241. THE NOMENCLATURE of Chemistry, now universally employed, was invented by the French chemists about 1784. Before that period, the names of chemical substances were entirely arbitrary, that is, each substance had an independent name, the signification of which had nothing to do with its composition, or often gave an erroneous idea concerning it. Thus, solution of muriate of lime was called *liquid shell*, and afterward *oil of lime.* Liquid ammonia was called *bone spirit*, and sulphuric acid was called *oil of vitriol.* It is true, at that time, the substances known to chemists were few in number, when compared with the immense list of the present day. But even then, their number was such as to make it difficult for the memory to retain them, and at the same time to remember their origin or composition, when this was known. At present, were the substances mentioned in any chemical book, merely designated by arbitrary names, or names inexpressive of their composition, the student would necessarily spend more time in learning and remembering them, than is now required to obtain a knowledge of the whole science of Chemistry. The general diffusion of chemical knowledge, therefore, is in a great measure owing to the present nomenclature—its perfect simplicity, its copiousness of meaning, and the ease with which it is learned and retained.

242. EACH TERM DESIGNATES THE COMPOSITION.—Each term in this nomenclature designates the composition of the compound substance to which it is applied; and as the simple substances are comparatively few, the composition of most chemical substances are known only by these names.

243. NAMES OF THE ACIDS DERIVED FROM THEIR BASES.—The names of the acids are derived from those of their bases, that is, from the names of the substances to which oxygen unites in such proportions as to form acids. Thus, sulphur is

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When was chemical nomenclature invented, and by whom? Before this invention, how were chemical substances designated? What is said concerning improper names before this invention? At present, were the substances known to chemists designated only by arbitrary names, what would be the consequence to the learner? What effect has this nomenclature had on the diffusion of chemical knowledge? By this nomenclature what do the names of the substances designate? From what are the names of the acids derived?

the base of sulphuric acid, and carbon is the base of carbonic acid. Some of these bases unite with several proportions of oxygen, and form acids of different degrees of strength. These proportions are designated by the different terminations of the name of the acid, the smaller proportion being signified by *ous*, and the larger by *ic*. Thus, sulphur*ous* and sulphur*ic*, and nitr*ous* and nitr*ic* acids, mean that these acids contain single and double proportions of oxygen. The *salts*, that is, the compounds which the acids form with alkalies, earths, and metallic oxides, also indicate by their names the substances they contain. Thus, the salts ending in *ite*, consist of a base, united to an acid, ending in *ous;* and a salt, ending in *ate*, contains an acid ending in *ic*. Sulph*ite* and phosph*ite* of potash are formed of potash and sulphur*ous* and phosphor*ous* acids, while sulph*ate* and phosph*ate* of potash denote compounds of sulphur*ic* and phosphor*ic* acids, united to the same base. The names of all the salts, of which there are nearly 2,000, denote their composition in the same manner, and thus we know the ingredients of their compositions by merely seeing their names. The termination *uret*, denotes the union of simple non-metallic bodies with a metal, a metallic oxide, or with each other. Thus, sulph*uret* and carb*uret*, or *sulphide* and *carbide* of iron, indicate a combination between sulphur, or carbon, with iron. As oxygen combines with several of the metals, in different proportions, but not always sufficient in quantity to form acids, the compounds so formed, though derived from the same metal, differ from each other. These compounds are called *oxides*, and are distinguished from each other by the Greek derivatives, *prot*, *deut*, *trit*, and *per*. *Prot*oxide signifies the first degree of oxidation; *deut*oxide, the second; *trit*oxide, the third; and *per*oxide, the highest. If it is a compound of one atom of acid and one of alkali, the generic name is employed, as carbonate of potash. But if two or more atoms of the acid be combined with the same base, a numeral is prefixed to indicate its composition in this respect. Thus, when the acid is in two proportions, or there are two atoms of acid to one of potash, it is

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What is the base of sulphuric acid? What is the base of carbonic acid? By what termination in the word is a weak acid designated? By what termination is the strong acid indicated? What are the compounds called which the acids f with different bases? If an acid ends in *ous*, what is the termination of the which it composes a part? If the acid ends in *ic*, how does the salt end? H you know the composition of a salt by merely hearing its name? What termination *uret* denote? What is the composition of a carb*uret* of sulphur are oxides? By what terms are the different oxides denoted? What is a d What is a *trit*oxide? What is a *per*oxide?

called *bi*-carbonate of potash. The three salts of oxalic acid and potash are called the oxalate, *bin*oxalate, and *quadr*oxalate of potash; the first consisting of one atom of each, the second of two atoms of acid to one of potash, and the third of four atoms of acid to one of potash.

244. When oxygen unites in more than two proportions with any base, the prefix *hypo* is used to denote a less degree of oxygenation than is indicated by *ous*. Thus, *hypo*sulphurous acid contains less oxygen than sulphurous, and hyposulphuric less than sulphuric.

Oxy denotes a dose of oxygen more than is indicated by *ic*; thus, *oxy*chloric acid is stronger than chloric acid. *Ter* denotes 3 equivalents as *terchloride.*

The terms *sub*, under, and *super*, above, are used with respect to the salts. When the components neutralize each other, it is a *neutral* salt; if the acid prevails, it is a *super*-salt; if the alkali, it is a *sub*-salt; but these terms are now obsolete. *Sesqui*, one and a half, is used when elements combine in the proportions of one and a half to one, or as three to two.

245. EXAMPLES.—The following examples will show how the numeral prefixes are used:

Triphosphuret of copper	1 eq. phosphorus	+3 eq. copper.
Dinoxide of copper	1 eq. oxygen	+2 eq. copper.
Subsesquiphosphuret cop.	1 eq. phosphorus	+1½ eq. copper.
Protoxide of copper	1 eq. oxygen	+1 eq. copper.
Susquioxide of copper	1½ eq. oxygen	+1 eq. copper.
Binoxide manganese	2 eq. oxygen	+1 eq. manga.
Teriodide of nitrogen	3 eq. iodine	+1 eq. nitrog.
Quadrachloride nitrogen	4 eq. chlorine	+1 eq. nitrog.

TABLE OF NAMES AND THEIR COMPOUNDS.

The following table shows at a view the names of the compounds, which some of the principal elements form, when combined with other substances.

Names.		Compounds.	Names.		Compounds.
Oxygen	forms	oxides.	Phosphorus	forms	phosphides.
Chlorine	"	chlorides.	Carbon	"	carbides.
Bromine	"	bromides.	Nitrogen	"	nitrides.
Iodine	"	iodides.	Hydrogen	"	hydrides.
Fluorine	"	fluorides.	Cyanogen	"	cyanides.
Sulphur	"	sulphides.			

What is said of *supersalts* and *subsalts*?

It will be observed that the former names of the sulphides, phosphides, and carbides, were *sulphurets*, *phosphurets*, and *carburets.*

CHEMICAL SYMBOLS.

246. The impracticability, in many cases, of contriving convenient names, expressive of the constitution of chemical compounds, especially of minerals, suggested the employment of symbols, as an abbreviated mode of denoting the composition of bodies. It was thought, the names of elementary substances, instead of being written at full length, might often be more conveniently indicated by the first letter of their names; and that the combination of elements with each other might be expressed by placing together, in some way agreed on, the letters which represent them. The advantage of such a symbolic language was felt so strongly by Berzelius, that he, some years ago, contrived a set of symbols, consisting of the initials of the Latin names of the elements, which he has since used extensively in his writings; and other eminent chemists, as well as mineralogists, believing symbols to be useful, adopted those which Berzelius had proposed. The consequence is, that symbolic expressions, called *chemical formula*, are now so much resorted to, and so identified with the language of chemistry, that essays of great value are, in a measure, sealed books to those who can not read symbols. It is, therefore, important, that those who are to make chemistry an object of science, or business, should not be unacquainted with these signs. The following table includes the symbols of all elementary bodies, according to Graham's last edition.

TABLE OF CHEMICAL SYMBOLS.

(Those in italics are rare, or newly discovered.)

Names of the elements.	Symbols.	Names of the elements.	Symbols.
1. Aluminum, ...	Al.	10. Calcium, ...	Ca.
2. Antimony, (Stilbium,) .	Sb.	11. Carbon, ...	C.
3. Aridium, ...	Ar.	12. *Cerium*, ...	Ce.
4. Arsenic, ...	As.	13. Chlorine, ...	Cl.
5. Barium, ...	Ba.	14. Chromium, ...	Cr.
6. Bismuth, ...	Bi.	15. Cobalt, ...	Co.
7. Boron, ...	B.	16. Copper, (Cuprum,) . .	Cu.
8. Bromine, ...	Br.	17. *Didymium*, ...	D.
9. *Cadmium*, ...	Cd.	18. Donarium, ...	Do.

What are carbonate and *bi*carbonate of potash? What is a ponderable body? What is a simple body? What is the difference between a simple and an elementary body? When do chemists call a body simple? What are the uses of chemical symbols? Who invented these symbols?

Names of the elements.	Symbols.	Names of the elements.	Symbols.
19. Erbium,	E.	43. Phosphorus,	P.
20. Fluorine,	F.	44. Platinum,	Pl.
21. Glucinum,	G.	45. Potassium, (Kalium,)	K.
22. Gold, (Aurum,)	Au.	46. Rhodium,	R.
23. Hydrogen,	H.	47. Ruthenium,	Ru.
24. Ilmerium,	Il.	48. Selenium,	Se.
25. Iodine,	I.	49. Silicon,	Si.
26. Iridium,	Ir.	50. Silver, (Argentum,)	Ag.
27. Iron, (Ferrum,)	Fe.	51. Soda, (Natron,)	Na.
28. Lathanium,	La.	52. Strontium,	Sr.
29. Lead, (Plumbum,)	Pl.	53. Sulphur,	S.
30. Lithium,	Li.	54. *Tantalum*, (Columbium,)	Ta.
31. Magnesium,	Mg.	55. *Tellurium*,	Te.
32. Manganese,	Mn.	56. *Terbium*,	Tb.
33. Mercury, (Hydrargyrum,)	Hg.	57. *Thorium*,	Th.
34. Molybdenum,	Mo.	58. Tin, (Stannum,)	Sn.
35. Nickel,	Ni.	59. Titanium,	Ti.
36. *Niobium*,	No.	60. Tungsten, (Wolfram,)	W.
37. Norium,	Nr.	61. *Uranium*,	U.
38. Nitrogen,	N.	62. *Vanadium*,	V.
39. Osmium,	O.	63. Yttrium,	Y.
40. Oxygen,	O.	64. Zinc,	Zn.
41. Palladium,	Pd.	65. Zirconium,	Zr.
42. Pelopium,	Pe.		

NOTE.—In some cases, the symbols represent the Latin, instead of the common names of the equivalents, as *Natron*, meaning soda. In such cases the terms are placed in brackets.

247. ABOUT SYMBOLS.—Sir Thomas Brande has invented, and employs, symbols differing in several respects from those of Berzelius above given; so that those who consult his works, and those of some other writers, will have to learn a new series of characters, to signify the same elements. Those of Berzelius are, however, employed by most authors who have adopted the symbolic system of chemical writing, both in this country and Europe. To those students, however, who intend only to obtain a general knowledge of chemistry, by going once or twice through a manual, these signs can not be considered of primary importance. When formulæ of considerable length and complexity are indicated by these signs, the student will, at first, find himself at a loss to comprehend them, and will, every moment, have to consult the table to understand what he sees. We have, therefore, in kindness to the student, thought best not to adopt them fully; at the same time, giving such explanations as the subject seems to require, so that those who desire it can become masters of the whole matter.

248. EXPLANATION OF CHEMICAL SYMBOLS.—These signs

are intended to represent the chemical equivalents of the elements. Thus, the letters H. I. and Ba. stand for one equivalent of hydrogen, iodine, and barium; and $2\ H$, $3\ H$, and $4\ H$, for 2, 3, and 4 equivalents of hydrogen. The formulæ for compound bodies are indicated by the elements they contain, and the mode in which they are united. This may be done in several ways, but the most common method is, to connect together the symbols by the same signs as are used in algebra. Thus, the formulæ $K+O$, $Ca+O$, $Ba+O$, $Mn+O$, $Fe+O$, $2\ Fe+3\ O$, $3\ H+N$, $2\ H+2\ C+2\ O$, $N+5\ O$, $S+3\ O$, and $H+Cl.$, denote single equivalents of potassa, lime, baryta, protoxide of manganese, protoxide of iron, sesquioxide of iron, ammonia, olefiant gas, carbonic acid, nitric acid, sulphuric acid, and hydrochloric acid. The formula $K+N+6\ O$, indicates the elements which are contained in an equivalent of nitrate of potassa: in order to express, further, that the potassium is combined with only one equivalent of oxygen, the remaining oxygen with the nitrogen, and the potassa with the nitric acid, the symbols are placed thus: $(K+O)+(N+5\ O,)$ the brackets containing the symbols of those elements which are supposed to be united. A number placed on the outside of a bracket multiplies the compound within it: thus $(K+O)+(S+3\ O)$ is sulphate of potassa, and $(K+O)+2\ (S+3\ O)$ is the bisulphate of potassa. All the elements contained in a compound are thus visibly represented, and the chemist is able readily to trace all the modes of combination, and to select that which is most in harmony with the facts and principles of his science. He may, and often does, thereby detect relations which might otherwise have escaped his notice.

The above is taken from the last edition of "Graham's Chemistry," and if teachers and students in this country adopt this method, the doctrine of chemical symbols will become generally understood and appreciated. Independently, however, of the vexation of learning such a number of signs, we can not perceive the utility of employing them for common purposes, though already learned. Thus bisulphate of potash, as seen above, is thus expressed, $(K+O)+(2\ S+3\ O.)$ Now, who does not see that the words themselves can be more quickly written than these signs made? and, when printed, close attention and much practice is required in order to avoid errors in reading them.

249. ISOMORPHISM.—This term comes from the Greek, signifying *like form*, and is applied to such substances as assume

the same crystalline forms, though composed of different elements, and having the same number of equivalents.

Also, the quality of a substance by which it is capable of replacing another in a compound, without any alteration of the previous crystalline form of the compound. This new branch of chemical science is particularly illustrated by the arsenic and phosphoric acids. Thus, the neutral phosphate and biphosphate of soda, have exactly the same crystalline forms as the arseniate, and biarseniate of soda. Each arseniate has a corresponding phosphate, possessed of the same form, possessing the same number of equivalents of acid, alkali, and water of crystallization, and differing, in fact, in nothing, except that one series contains arsenic, and the other an equivalent quantity of phosphorus.

These examples are sufficient to show the meaning and scope of isomorphism. Many other cases of the same kind are to be found described by chemical authors.

250. Isomerism.—This term is a Greek compound, and signifies *equal parts*, and in chemical science is applied to certain compounds, which, though they have the same elementary equivalents, possess entirely different properties.

Such bodies have in general been found, by the progress of discovery, to agree in the relative proportion of their constituents only, and to differ in the aggregate number of the atoms composing them, or in the mode of arrangement of these atoms; and although new cases of isomerism are constantly arising, others are removed as they come to admit of explanation. In the abstract, Isomerism is an improbable phenomenon, since a difference in the properties of a compound, without a difference in their composition, would seem to be an effect without a cause. In some of these cases, however, although the relative proportions of the compound are identical, the number of atoms of each are different. These are shown by

Oil of lemons, .	10 eq. carbon.
" " . .	8 eq. hydrogen.
Oil of turpentine,	20 eq. carbon.
" " . .	16 eq. hydrogen.

Here we see that although the relative proportions of each are the same, the number of combining atoms differ, and hence the entire difference in the nature of these two bodies.

What is the meaning of Isomorphism? What examples are given? What is the meaning of Isomerism? How is this term applied to chemical compounds?

PART II.

CHAPTER XIII.

PONDERABLE BODIES.

251. Explanations.—A *ponderable* body is one which has appreciable weight.

A *simple* body is one which has not been decomposed. These are also called *elements*, or *elementary* bodies.

It is possible that all the substances now called elementary, may still be in reality compounds, for our knowledge on this subject is entirely negative, that is, all bodies which the art of chemistry has been unable to separate into parts, or to decompose, are called *simple*, in order to distinguish them from known compounds. Before the refinements of chemical analysis were known, it was believed that nature afforded only four elements, viz., *fire*, *air*, *earth*, and *water*. Analysis has, however, shown, that fire, or heat, is the result of chemical union; that air is a compound of nitrogen and oxygen; that there are many earths, and that water is composed of hydrogen and oxygen.

252. Number of elements.—The number of simple, or elementary substances, as arranged under the head of chemical symbols, now amount to sixty-five. Of these, much the largest proportion are metals, or metallic bodies, seven or eight of which have been discovered within a few years.

Not long since, potash, soda, and many other substances, which the refinements of chemistry have shown to be compounds, were supposed to have been elements; and it is not improbable that some now rated as simple bodies, will prove to be compounds.

253. Transferring the gases.—Before proceeding to describe the properties of the gases, it might be thought necessary to detail more particularly than has been done, the modes of confining and transferring them from one vessel to another But it is thought that such directions are better understood by

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How many elements were formerly supposed to exist? What is said concerning fire, air, earth, and water? How many elements are now supposed to exist, and what are they? What is said of the probability that some bodies now arranged as elements will be found to be compounds?

the student, and much more readily followed when given in connection with the particular subjects or cases to which they immediately apply. The method, for instance, of transferring the nitrous oxide from the retort to the gasometer, and from the gasometer to the gas bag, will be best understood if given in connection with an account of the properties of the gas, or immediately after it. The same, it is thought, may be said of confining and transferring the other gases. As several different methods are required, depending on the nature of the gas, its absorption by water, its specific gravity, and other properties, these different modes can be best explained and understood in immediate connection with the description of the peculiar properties of each gas.

254. DEFINITE PROPORTIONS.—As the doctrine of definite proportions is not only highly interesting as a subject of philosophy, but is also intimately connected with chemistry, both as a science and a practical art, we shall attach to the name of each substance at the head of sections, its equivalent number, so that the reader may at once observe its combining proportion. And it is earnestly recommended to the pupil, that he should not only regard this subject as one of great importance in a scientific relation, but also, when viewed in a different light, as one that tends directly to impress the mind with the most serious conviction that nothing in nature has been left to chance, but that the Almighty Creator has left a witness of Himself, even in the proportions and arrangement of the atoms of matter. Nothing, perhaps, even the sublimest works of nature, are more calculated to elicit the wonder and astonishment of a reflecting mind, than the fact that substances combine with each other in exact and definite quantities, and that these quantities or proportions, are the same in relation to the same substance throughout the world, and have been so ever since the creation. This discovery may be considered as a new proof, directed expressly to the present age, that the most minute works of what we call nature, do indeed bear the most indubitable marks of divine agency and design.

255. But while the discovery itself is an evidence of the profound philosophy of the present age, the development of its principles, by the constant accession of new ideas, is calculated

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What is said of the doctrine of definite proportions, in relation to philosophy and chemistry? In what other respects is this subject recommended to the particular attention of the pupil? What is said of divine agency and design in the minute works of nature? After all human acquirements, how much do we know of the laws and operations of nature?

rather to humble the pride of human knowledge, by as constant a conviction, that after all our acquirements, we know comparatively nothing of the laws and operations of nature. The very fact, that the laws of proportions, now comparatively just known to man, have existed ever since the creation of matter, and have been in perpetual exercise all over the universe, without a suspicion of their existence, is of itself a sufficient proof of the almost entire ignorance of man even of the phenomena of nature, and a still stronger proof of his ignorance of her laws. And if facts, in themselves so simple, yet so wonderful, and when once known, so obvious, have escaped the observation of man for thousands of years, is it not probable that phenomena are constantly going on before our eyes, which, could we understand them, would astonish us still more, and at the same time afford a still stronger conviction of our ignorance, and want of penetration?

These considerations, while they are calculated to humble the pride of human intellect, by showing how little we know of the laws which govern even the ordinary operations of nature, ought, by the conviction of ignorance, to prove an incentive to constant observation on natural phenomena, that, if possible, we might arrive at the knowledge of their true causes.

CHAPTER XIV.

INORGANIC CHEMISTRY.—NON-METALLIC SUBSTANCES.

OXYGEN.

Equivalent, 8. Symbol, O.

256. The name *oxygen* is derived from two Greek words, and signifies the *former* or *generator of acids*, because it enters into the composition of most acid substances, and was formerly considered the universal and only acidifying principle in nature.

It was discovered by Dr. Priestley, in 1774, and named by him *dephlogisticated* air. Its specific gravity is 1.11, air being 1. It is a non-conductor of electricity, like common air. Its

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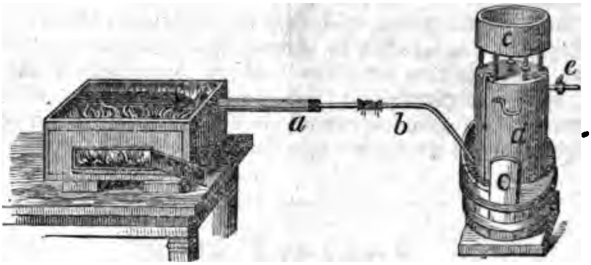
What is proved by the fact, that the law of definite proportions, though existing ever since the creation of matter, have, until lately, remained unknown? What is said of the probability that wonderful phenomena are constantly going on before our eyes? What does the term oxygen signify? Who discovered this gas? What is the specific gravity of oxygen gas?

electrical state is always negative, and when suddenly and forcibly compressed, as in the fire-pump, already described, it emits light and heat.

Oxygen may be obtained from many substances. The peroxides of lead, or manganese, and the nitrate and chlorate of potash, all yield it in abundance, when merely exposed to a dull red heat.

257. From manganese.—A convenient substance for this purpose is black, or peroxide of manganese, in the state of fine powder. This, when heated in an iron bottle, or gun-barrel, will yield upward of 120 cubic inches of the gas to an ounce of the oxide. For small experiments, a gun-barrel may be used; but where considerable quantities are wanted, a wrought-iron bottle, with a neck 18 inches long, is the best instrument.

FIG. 66.



Oxygen from Manganese.

258. Into such a bottle introduce three or four pounds of the black manganese, in powder, and having placed it in a furnace, as shown by Fig. 66, on making the fire, oxygen gas will, in a few minutes, come over in abundance. The neck of the bottle, *a*, is connected with the glass, or lead tube, *b*, leading to the gasometer. This vessel is formed of two cylinders, *c* and *d*, placed one above the other, with tubes communicating between them, through which the water passes to fill the lower cylinder, on being poured into the upper one. Two of these tubes reach to the bottom of the lower cylinder, and the other two are stopped with thumb screws.

What are the substances from which it can be obtained? What is the cheapest and most convenient mode of obtaining it? How many cubic inches of this gas will an ounce of the black oxide of manganese yield? What are the methods described of extricating this gas from manganese? Describe the method of obtaining oxygen gas by means of an apparatus. Fig. 66.

259. Before the escape of the gas from the retort, the gasometer must, of course, be filled with water. This is done by pouring it into the upper cylinder, the stop-cock, *e*, being open, for the exit of the air. Now, on stopping the communication between the two cylinders, and turning the stop-cock, *e*, it will be seen that the gas now to be admitted, can not escape by the long tubes from the upper cylinder, since their mouths are under the water, nor by the others, since they are closed by stop-cocks. The first portions of the gas are impure, and may be let off at *e*, until the wick of a candle just blown out, takes fire on being held in the current. In these gasometers, there is a glass tube on the outside, to show the quantity of water or gas it contains. The tube by which the gas is admitted, must be curved down from such a height as to prevent the water in the gasometer from flowing back into the retort. As the gas is let in, the water is allowed to escape by a stop-cock, through which the tube passes to admit the gas, this being closed when the gasometer is full. The upper cylinder being open, water is poured into this, to increase the pressure on the gas in the lower one. By fixing a tube at *e*, and opening the stop-cock, and pouring water into the upper cylinder, the gas may be transferred to any place where it is wanted. By fixing a jet-tube and stop-cock to the gas holder, and directing a jet of oxygen through the flame of an alcohol lamp, nearly all the effects of the compound blow-pipe may be obtained.

260. Theory.—With respect to the theory of the above process, it is necessary to state, that there are three oxides of manganese, each, of course, containing different proportions of oxygen. These oxides are thus constituted, the combining proportion of manganese being 28, and that of oxygen 8.

Protoxide manganese, 28, added to oxygen, 8=36.
Deutoxide, . . . 28, " " 12=40.
Peroxide, ... 28, " " 16=44.

When the peroxide is exposed to a red heat, it parts with half a proportion of oxygen, that is, 4 parts, the number for oxygen being 8, and is therefore reduced to a deutoxide, whose number, it will be observed, is 40. The number for the peroxide being 44, and the loss by a red heat being 4, we obtain 4

In what manner may the effects of the compound blow-pipe be obtained by this gas, and a spirit lamp? How many oxides of manganese are there, and what are the proportions of oxygen in each? What proportion of oxygen does the peroxide part with at a red heat?

grains of oxygen for every 44 grains of the oxide, which in bulk is nearly 12 cubic inches, making about 128 cubic inches for each ounce of the oxide.

When oxygen is obtained by means of sulphuric acid, the theoretical expression is different. In this case the peroxide loses a whole proportion of oxygen, and is thus converted into a protoxide, which then combines with the acid, forming a sulphate of manganese, which remains in the retort. By this process, therefore, the peroxide yields 8 grains of oxygen to every 44 grains employed; but in practice it is found that the first method is the best and cheapest.

261. It will be observed, that the weight of oxygen for the deutoxide, expressed above, is only 12, being a proportion and a half, instead of two proportions of that element. The oxides of lead and iron afford examples of precisely the same kind. These facts were at first supposed to afford exceptions to the law of definite proportions, or rather to the atomic theory, by which the cause of definite quantities is explained. But it will be remembered, as already stated, that the smallest proportions in which bodies have been found to combine, by weight, are those by which they are represented in numbers. Now the smallest proportion in which oxygen has hitherto been known to combine, is in water, this proportion being as 8 to 1. The number, therefore, for oxygen is 8.

262. FROM RED OXIDE OF MERCURY.—The ingenious student who has a strong desire to witness the effects of oxygen on various substances of which he had so often read, may obtain enough for his purpose from several compounds, most of which are easily obtained. In addition to the oxides of lead and manganese, and the chlorate of potash, already named, oxygen is readily obtained from the *red oxide of mercury*, or *red precipitate.* In this compound the affinity which holds the mercury and oxygen together is so feeble, that simple exposure to the heat of a lamp suffices to effect decomposition.

The apparatus for this purpose is shown by Fig. 67, where *a* is a tube of glass, stopped with a cork, through which passes the end of the glass tube, *b*, bent as in the figure, so as to open under the receiver, *c*, which is filled with water, and stands on the shelf of a pneumatic trough. The precipitate being placed

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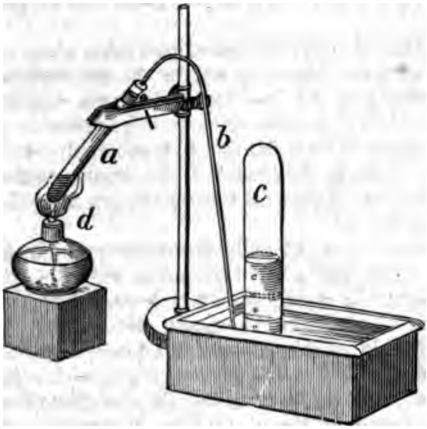
To what oxide is the peroxide reduced by parting with a portion of its oxygen? What does deutoxide mean? Explain the chemical changes which take place when the oxygen is obtained by means of sulphuric acid. What is said concerning the weight of oxygen for the deutoxide of manganese? Describe the means of obtaining oxygen from red precipitate and chloride of potash.

in the tube, for which a retort of larger size may be substituted, the heat of the spirit lamp, *d*, soon extricates the oxygen, which will be seen to rise through the water. By having several such receivers filled with water, the student may fill and remove, one after the other, or by upward pouring transfer the gas to other vessels, only taking care to keep their mouths under the water of the cistern during the process. Instead of the red precipitate, the chlorate of potash may be used, which yields very pure oxygen. If the chlorate is mixed with one-half its weight of oxide of manganese, it will require less heat than when used alone.

FIG. 67.



Oxygen from Red Precipitate.

Oxygen gas is an invisible transparent fluid, like common air, and has neither taste nor smell. It is sparingly absorbed by water, 100 cubic inches of which, take up three or four cubic inches of the gas.

263. UNIVERSAL AFFINITY OF OXYGEN.—Oxygen has the most universal affinity of any known substance, there being not one of the simple substances with which it may not be made to combine. It unites with all the metals, forming a very extensive class of compounds, known under the name of *oxides.*

What is said of the taste and smell of oxygen? In what proportion in this gas absorbed by water? What is said concerning the extensive affinity of oxygen?

With some of them it combines in such proportions as to form acids. Such is the case with arsenic, molybdena, and others. With the simple combustibles, sulphur, carbon, &c., it also combines in various proportions, forming oxides and acids. With the metals sodium and potassium, it enters into combination to form the alkalies soda and potash. Thus the acids and alkalies, though in most of their proportions so entirely opposed to each other, are composed of oxygen united to different bases, the base of sulphuric acid being sulphur, and that of potash being potassium.

The process of oxidation sometimes takes place very slowly, as in the rusting of iron exposed to the atmosphere. In this case the affinity of the iron for the oxygen contained in the atmosphere, though constantly exerted, produces its effects very gradually, particularly if the iron is kept in a dry state; but the oxidation is greatly facilitated if the iron is moistened with water, since, then, the metal absorbs oxygen from the water, as well as from the air.

264. COMBUSTION, WHAT?—In ordinary combustion, which is nothing more than a rapid oxidation, with the extrication of heat and light, the strong affinity between the combustible and the oxygen is caused by the great elevation of temperature. The combustible requires, in the first place, to be heated to a certain degree, before it will attract oxygen with sufficient force to emit heat and light, after which, the elevation of its temperature is continued by the absorption of oxygen, and thus the combination of one portion of oxygen with the burning body, causes the absorption of another.

A *combustible* is any substance, capable of uniting with oxygen, or any other supporter of combustion, with such rapidity, as to cause the disengagement of heat and light. In this sense, iron, steel, and many other bodies, though they will not burn in the open air, are strictly combustibles, as they conform to the above definition, when heated in oxygen gas.

In this gas, all combustibles burn with greatly increased splendor; and many substances which, before the discovery of this gas, could not, in any sense, belong to this class, are now strictly combustibles.

What are the compounds of oxygen and the metals called? Does it ever form acids by combining with the metals? When combined with the metals potassium and sodium, what are formed? What is said of the spontaneous oxidation, or rusting of iron? What is ordinary combustion? In combustion, what causes the strong affinity between the burning body and oxygen? In kindling a fire, why is it necessary to raise the temperature of the wood, in order to make it burn? What is a combustible body? In what sense are iron, steel, and other metals, combustibles?

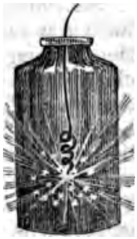
The combustion of various substances in oxygen gas affords experiments of the most brilliant and instructive kind.

Among these, the combustion of iron, steel, and zinc, are highly interesting, not only because we are not in the habit of seeing metals burn, but because the first give out the most splendid coruscations of light, while the zinc burns with a light peculiar to itself.

265. Combustion of steel in oxygen gas.—To exhibit the combustion of iron or steel in this gas, procure a piece of wire of small size, or what is better, a watch-spring, and wind it round a slender rod of wood, so as to coil it in a spiral form, the turns of the coil being about the fourth of an inch apart. Then withdraw the rod, and fix to the lower end of the coil a small piece of thread dipped in melted bees-wax, or sulphur, or what is better, a little piece of spunk. The other end of the wire, for a few inches, is to be left straight, and fixed to the cork fitting the mouth of the bottle in which the experiment is to be made.

Next, fill a clear glass bottle, of a quart or more capacity, with oxygen gas, and having set it upright, cover the mouth with a plate of glass, or otherwise. Then inflame the combustible on the end of the wire, and having removed the cover from the bottle, introduce the coil, and fix the cork in its place, as represented by Fig. 68.

FIG. 68.



Combustion of Steel.

266. Intense light.—The wire will burn with a light too vivid for the eyes to bear, throwing out the most brilliant coruscations in every direction. Now and then a globule of the melted metal will fall, and if the vessel contains water, it will leap on its surface for an instant or two, being thrown up by the steam into which it converts the fluid. If the vessel contains no water, the intense heat of the globule will cause it to melt the glass, and sink into its substance, and if the glass be thin, it will fuse a path quite through it, without causing the least fracture.

267. Combustion of zinc.—To witness the combustion of zinc in oxygen, first prepare the metal by melting, and pouring

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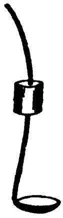
What is said of the brilliancy of the combustion of some of the metals? How is the iron wire prepared for combustion in oxygen gas? Describe Fig. 68. What causes the globules of melted iron to leap on the surface of the water? What is said of the action of the globules of metal on the glass? Describe the method of preparing and burning zinc in oxygen gas.

it, while fluid, into the water. Then place some thin pieces in a spoon, prepared with a cork on its handle, as represented by Fig. 69, and put in the midst of the zinc a small piece of phosphorus. Having a bottle of the gas prepared, as in the last experiment, inflame the phosphorus by holding the spoon over a lamp, and instantly introduce it into the bottle, fixing the cork in its place. The metal will burn with the beautiful white light, often tinged with green, owing to a small quantity of copper which the zinc contains.

FIG. 69.



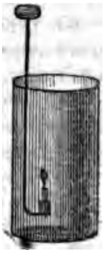
Spoon.

If a lighted candle be blown out, and then plunged into a vessel of this gas, while a spark of fire remains in the wick, it will be re-lighted with a slight explosion.

The best way of making this experiment is, to place a short piece of candle in a socket, fixed to a wire, as in Fig. 70. In this manner a candle may be blown out and again set on fire by dipping it into a bottle of oxygen, twenty or thirty times, and perhaps oftener.

268. Changes by combustion.—During combustion in oxygen gas, the oxygen combines with the burning body, and produces remarkable changes, not only on the combustible, but also on the gas. The combustible, on examination, will be found to have sensibly increased in weight, by the combination, while the oxygen entirely loses the power of again supporting combustion, so that if a lighted candle be plunged into it, instead of burning with splendor, as before, it is now instantly extinguished.

FIG. 70.



Candle in Oxygen.

These changes are readily explained by the analysis of the body burned, and of the gas. The iron loses its brilliancy, and is converted into a dark brittle substance, easily pulverised in a mortar. This is an *oxide* of iron, and consists of the iron itself united to the ponderable portion of the gas. If the iron is weighed before the combustion, and afterward, it will be found to have increased in weight in the proportion of 8 parts to the 28.

269. Loss of weight by combustion.—The gas, on the contrary, loses in weight what is gained by the iron; and if the

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What is the effect when a candle is blown out, and then instantly plunged into the gas? What effect does combustion produce on oxygen gas? What change is produced on the iron burned in it?

vessel in which the experiment is made, be open at the bottom, and stands in a dish of water, the diminution of the gas in volume will be indicated by the rise of the water in the vessel. If the gas and iron are both accurately weighed before the experiment and afterward, the sum of their weights will be found precisely the same, proving that nothing has escaped, and that what has been lost by the oxygen has been gained by the iron. When other combustibles are submitted to the action of this gas, though they may entirely change their appearance by the process, or seem to be dissipated and consumed, yet nothing is lost by the burning, there being in all such instances merely a change of form. Thus, when charcoal or diamond is burned in a confined portion of this gas, instead of losing, as in the former experiment, the gas increases in weight, that is, it is converted into *carbonic acid gas*, by a union between the oxygen of the gas, and the carbon of the diamond or charcoal, so that what is lost by the charcoal is gained by the gas.

270. Destroys animals.—In every instance the gaseous matter which remains in the vessel after combustion, is unfit to support animal life. If a bird or any other animal be confined in a limited portion of atmospheric air, it soon dies, because it destroys the oxygen the air contains, by converting it into carbonic acid; thus leaving another portion of the atmosphere called *nitrogen*, both of which are destructive to life. (*See Nitrogen.*)

If a bird be confined in a portion of oxygen, it will live longer than in the same quantity of atmospheric air, because it is the oxygen alone which supports the respiration; but it dies when the oxygen is consumed, or converted into carbonic acid. But if any animal be introduced into a portion of air after its oxygen has been destroyed, or absorbed by a burning body, it dies in a few seconds, unless, like the frog, it has the power of suspending its respiration.

271. Caution about wells.—Finally, it is proper to remember, *that no animal can live in an atmosphere which will not support combustion.*

Why does the oxide of iron weigh more than the metal before it was burned? Suppose the iron and oxygen are both accurately weighed before and after the experiment, what effect on their weights will be produced by the combustion? Is any thing lost by combustion? When charcoal is burned in a confined portion of oxygen gas, what effect is produced on each? Into what gas is the oxygen converted by the process? Will the gas left after combustion ever sustain animal life? Why will a bird or any other animal soon die when confined in a limited portion of common air? Why will an animal live longer in oxygen gas, than in the same portion of common air? Will an animal live in air which will not support combustion? Will air which is unfit for respiration support combustion?

Were this fact more generally known and remembered, we should not every year hear of instances where lives are lost by descending into old wells or cisterns. The cause of such accidents is the presence of carbonic acid in the bottom of such cavities; and were the precaution taken to let down a burning candle, before the descent of the person, all danger might be avoided; for if the flame is extinguished, the air will not support animal life.

It has been recently reported, that throwing buckets of water into a well, where two persons had fallen down by suffocation with carbonic acid gas, had been the means of saving their lives. (*See Carbonic Acid.*)

HYDROGEN.

Equivalent, 1. Symbol, H.

272. The name of this gas is derived from two Greek words, signifying the *generator of water*, because it enters largely into the composition of that fluid.

It was discovered by Mr. Cavendish in 1766. Its specific gravity is 0.069, air being 1.—100 cubic inches weigh 2.11 grains, while the same bulk of air weighs 30.5 grains; it is, therefore, about 14 times lighter than atmospheric air. Compared with oxygen, it is just 16 times lighter than that gas; being indeed the lightest of all known ponderable bodies. It refracts light more powerfully than any other body, its refraction being in the ratio of 6.6, air being 1. Its electricity is positive.

273. How OBTAINED.—Hydrogen may be obtained by several processes, but in no instance without the presence of water, it being evolved only by the decomposition of that fluid.

The most convenient method, is to put fragments of iron or zinc into a proper vessel, and pour on them two parts by weight of sulphuric acid, diluted with 5 or 6 parts of water. The hydrogen will immediately ascend through the water in abundance.

Where only small quantities of hydrogen are wanted, the apparatus, Fig. 71, is sufficient. It consists of a flask of thin

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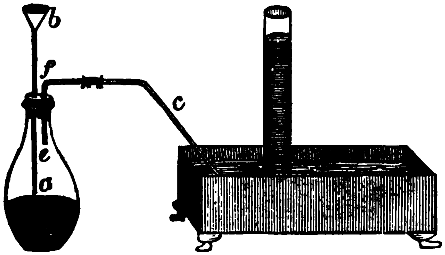
What precaution ought always to be taken before a person goes into a well or old cistern? What is the derivation of the word hydrogen? What is the weight of 100 cubic inches of this gas? What is its weight when compared with air? How much lighter is hydrogen than oxygen? What substance is lighter than hydrogen gas? What is said of its power to refract light? What is the electrical state of this gas? Can this gas be obtained without the presence of water? Why? What is the best method of obtaining this gas?

glass, *a*, into which the granulated zinc is put, and then the cork, with the tubes, *b* and *e*, *f*, passing through it, is put in its place. The tube, *c*, passes under a vessel filled with water, and inverted in the cistern, as shown by the figure. When every thing is prepared as shown and described, pour the diluted acid through the funnel *b*, and the gas will instantly begin to rise in the bell glass, as its bubbles will show. The first portions must be thrown away, as it will be mixed with atmospheric air, and therefore liable to explode. Zinc for this purpose is granulated by melting, and pouring into water. It dissolves more readily than iron.

FIG. 71.



Hydrogen by Acid and Zinc.

274. THEORY.—The production of the hydrogen depends on the decomposition of the water which is effected by the united action of the metal and acid. The metal, having an attraction for oxygen, obtains it from the water; this forms an oxide of the metal which is instantly dissolved by the acid; the surface of the metal is thus left clean, and exposed to the water, from which it attracts another portion of oxygen, which is dissolved as before. Meanwhile, the hydrogen being thus detached from the oxygen, absorbs caloric, and is evolved in the form of hydrogen gas.

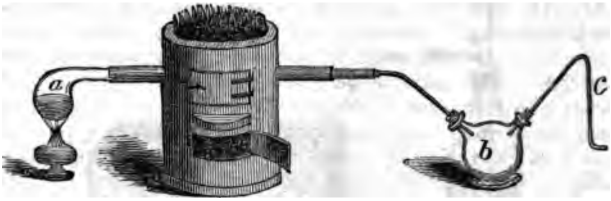
275. PROCESS WITH A GUN-BARREL.—Hydrogen may also be obtained abundantly by passing the steam of water through a hot iron tube. In this case, the oxygen combines with the iron, while the hydrogen is evolved.

This process may be performed in the following manner.

On what does the production of hydrogen depend? Explain the chemical changes which take place during the production of this gas? By what other method may this gas be obtained? How does the red hot gun-barrel decompose the water?

Nearly fill a gun-barrel with iron turnings, the cleaner and brighter the better. Then place the barrel across a furnace, as shown by Fig, 72, and attach to its end, by means of a perforated cork, a glass or lead tube, to be connected with the glass flask, *b*. This is done to prevent the possibility of the water in the cistern, where the gas is received, from finding its way into the red hot gun-barrel, which it might otherwise do if the steam in the retort, *a*, should be condensed. The retort, *a*, over a lamp, contains the water, and the tube, *c*, leads to the vessel where the gas is to be collected. This is commonly an inverted bell glass, filled with water, and standing in a trough or cistern. Being thus prepared, kindle a charcoal fire in the furnace, and light the lamp under the retort. As the water boils, the steam passing through the barrel among the red hot iron, will be decomposed, as above stated, while the hydrogen will come over in abundance, and passing through the flask, *b*, and the tube, *c*, will be collected in the vessel prepared to receive it.

FIG. 72.



Hydrogen by a Gun-barrel.

Hydrogen, when obtained by either of these methods, is not quite pure, but contains a little sulphur or carbon. For particular purposes, it may be purified by passing it through a solution of pure potash in water.

In this state hydrogen is without color, taste, or smell. It is, so far as is known, an elementary body, having resisted all attempts to resolve it into more simple parts.

276. DOES NOT SUPPORT COMBUSTION.—It is inflammable, but not a supporter of combustion. If a lighted candle be introduced into a vessel of this gas, the flame is instantly extin-

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Is hydrogen a compound or an elementary body? When a lighted candle is plunged into this gas, does it continue to burn, or is it extinguished? As the candle passes into the gas, what part of it is set on fire?

guished, but in passing into the gas, it inflames that portion which is in contact with the atmosphere. This shows that the combustion of hydrogen requires the aid of oxygen, which it absorbs from the atmosphere as a supporter.

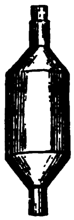
This experiment may be made by inverting the vessel containing the hydrogen in the open air, its levity preventing it from escaping downward. In this state it will be seen to burn only on the lowest surface. But if the vessel containing it be turned upright, the whole will escape in a volume of flame.

277. Is **USED FOR BALLOONS.**—Hydrogen is the gas with which balloons are charged, and being about fourteen times lighter than common air, if the balloon is large, it ascends with great force. The principle on which balloons ascend, is the difference of specific gravity between the balloon as a whole, consisting of hydrogen, and the apparatus containing it, and the same bulk of atmospheric air. It is the same principle that makes a cork rise through water, or a leaden bullet through quicksilver.

The principle of balloons may be illustrated thus: Fill a bladder, or a gas bag, furnished with a stop-cock, with hydrogen gas; attach to the stop-cock a tobacco-pipe, or what is better, one of metal. Then dip the bowl of the pipe into a solution of soap, and form bubbles by pressing the bladder. These bubbles being detached from the pipe, will rise rapidly through the air.

278. **DETONATES WITH OXYGEN.**—When hydrogen is mixed with oxygen and inflamed, the mixture detonates violently. The best proportions are two parts of the hydrogen and one of oxygen by volume. If soap bubbles of this mixture are touched with a candle when floating in the air, they give a report as loud as a pistol, but much more sharp and stunning.

FIG. 73.



Hydrogen Gun.

A loud report is also given when the hydrogen is mixed with common air, instead of oxygen. The best proportions are about three of the air to one of the hydrogen.

This experiment may be varied by means of the *hydrogen gun*, Fig. 73. It consists of a tin vessel, holding about a pint, the lower end being closed, and the upper end left open and fitted with a cork,

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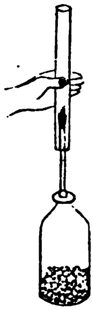
How is this experiment best made? Why does the hydrogen burn only on the surface? With what gas are balloons filled? On what principle do balloons ascend? How may the principle of balloons be illustrated? What is the consequence of firing a mixture of hydrogen and oxygen?

a small orifice being made toward the lower end, as seen in the figure.

Having filled this vessel about one-third with water, close the small orifice with the thumb, and let in hydrogen till the water is displaced. Thus, the vessel will contain three parts of air and one of hydrogen. The cork being put rather loosely in its place, the mixture is fired by raising the thumb, and applying a lighted taper to the orifice. The cork will be driven out with violence, attended with a loud report.

279. Musical tones.—When a jet of hydrogen is burned at the end of a tube with a fine bore, and within a large tube of glass, porcelain, or metal, musical tones are produced, which are grave or acute in proportion to the size or kind of tube employed.

FIG. 74.



Musical Tones.

This pleasing experiment may be performed by placing the materials for making hydrogen in a convenient vessel, furnished with a tube, as in Fig. 74. Or the tube may be connected with a reservoir of gas already collected. The manner of holding the large tube to produce the musical tones is shown in the figure.

Hydrogen can not be breathed without deleterious effects, though it is not immediately fatal to animal life.

280. Action of platinum sponge on hydrogen.—The action of platinum sponge on hydrogen is singular and highly curious. When a jet of this gas is directed on a few grains of the sponge, both being cold, and in the open air, the latter immediately becomes hot, and in a moment glows with a red heat, setting fire to the hydrogen.

Platinum sponge is prepared by dissolving the metal in *nitro-hydrochloric* acid, that is, a mixture of 1 part of nitric to 2 parts of muriatic acid. Ammonia, or muriate of ammonia, is added to this solution, which produces a yellow precipitate. When this precipitate is exposed to a red heat in a crucible, the acids and ammonia are driven off, and there remains pure platinum, in the form of a delicate spongy mass. Another method

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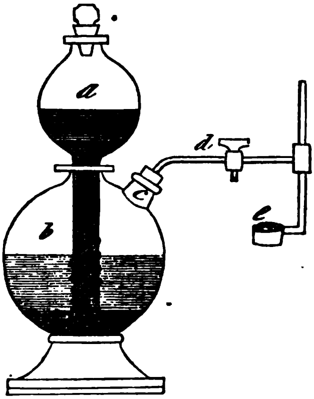
What proportions of each make the loudest report? What are the best proportions for mixing hydrogen and air for the same purpose? Describe the method of using the hydrogen gun, Fig. 73. How are musical tones produced by the burning of hydrogen? Explain Fig. 74. Is hydrogen a respirable gas? What effects does it produce when breathed? What phenomena are produced when hydrogen is thrown in a stream upon platinum sponge?

of obtaining the sponge is, to throw the yellow precipitate on filtering paper, and when the liquid has passed through, to dry the paper, and introduce it, with the adhering precipitate, into the crucible.

281. This curious effect of the action between platinum sponge and hydrogen, was discovered by Professor Dobereiner, of Jena, who invented the following method of producing an instantaneous light by its means.

FIG. 75.



Platinum Sponge and Hydrogen.

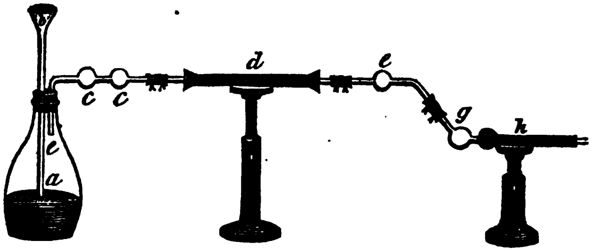
The two vessels, *a* and *b*, Fig. 75, are of glass; *a* is prolonged in the form of a tube, and is fitted to the mouth of *b*, by grinding, or cement, so as to be air-tight. The lower part of *a* reaches nearly to the bottom of *b*, and is encompassed with a strip of zinc. Sulphuric acid, diluted with five or six parts of water, being placed in *b*, *a* is fixed in its place, as seen in the figure. Hydrogen is evolved by the action of the acid on the zinc, and pressing upon the fluid, (which must fill only about one-half of *b*,) drives it up the tube into *a*. The stopper of *a* is conical, and rises to let the air from that vessel escape. When so much gas has been evolved as to press most of the acid up into *a*, and consequently to remove it from the zinc, the chemical process will cease, leaving *b* nearly filled with hydrogen. The brass tube, *d*, is cemented to the neck, *c*, and furnished with a stop-cock. The box, *e*, contains the platinum sponge at the end of the tube.

When a light is wanted, nothing more is necessary than to open the stop-cock *d*, and let a jet of the gas blow upon the sponge, which becoming immediately red hot, a match, and then a candle may be lighted. By permitting the hydrogen to escape, the acid again comes in contact with the zinc, and thus another portion of the gas is formed, and retained until wanted.

How is the platinum sponge prepared? Explain Fig. 75, and show how hydrogen is produced, and in what manner it is thrown upon the sponge.

282. **Decomposition of metallic oxides by hydrogen.**—Many metallic oxides when heated slightly in hydrogen gas, give off their oxygen to form water with that gas, at the same time the oxide is decomposed by the loss of one of its components. Thus, while one compound is decomposed, another is forming from one of its elements, and by proceeding carefully we can detect the exact composition of each.

FIG. 76.



Decomposition by Hydrogen.

283. The apparatus, Fig. 76, is designed for this purpose. It consists of the flask, *a*, in which the hydrogen is slowly generated by first introducing pieces of zinc, and then pouring through the pipe, *b*, sulphuric acid much diluted. In general, a little water in the form of vapor rises with the hydrogen, for the collection of which the two bulbs, *c*, *c*, are designed. If the gas still contains vapor, this is entirely withdrawn by passing through the tube, *d*, which contains dry chloride of lime, a salt having a remarkable attraction for water. It therefore passes into the globe, *e*, in a perfectly dry state.

The ball, *e*, contains the metallic oxide to be decomposed, that of copper, for instance. After the apparatus is filled with hydrogen, this ball is heated by means of a spirit lamp, until the oxygen begins to be evolved, when uniting with the hydrogen, the heat thus produced keeps the copper red for a considerable time, thus producing a curious little self-acting furnace, the heat expelling the oxygen from the copper, which in its turn becomes the means of furnishing the heat. Before the process begins, the ball, *e*, is weighed empty, and then with its

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Why does not the acid constantly act upon the zinc? When one portion of the gas escapes, in what manner is another portion generated?

oxide of copper in it, and thus the weight of the copper is known. The weight of the globe, *g*, is also found, as well as that of the chloride of lime in the tube, *h*. The water that is formed in *e*, passes down into *g*, and if any vapor escape from *g*, it will be absorbed by the chloride of potash in the tube *h*. At the end of the process, the weight of the water formed will be found by weighing the globe *g*, with the water in it, and also weighing the chloride in *h*, and comparing the sum of these weights with what they weighed before. The loss of weight in *e*, will show how much oxygen was given off by the oxide of copper, and thus by estimation the bulk of oxygen can be known which the oxide of copper gave out. The quantity of hydrogen contained may also be estimated by that of the oxygen, the weight of this being known. Thus, the definite proportions of the elements of water, and the composition of an oxide may be ascertained by the same process.

PROTOXIDE OF HYDROGEN.

Equivalent, 9. Symbol, OH.

1 eq. Oxygen, 8+1 eq. Hydrogen, 1.

WATER.

284. It is only necessary to remark in respect to the above abbreviations, that the number for water, as already explained, is 9, being composed of 1 proportion of oxygen 8, and one proportion of hydrogen 1. The same method being observed with respect to the other substances to be described, the student has only to notice the numbers affixed to the names of each substance, and he at once becomes acquainted with the proportions and compositions of each compound, and the number by which the compound itself is represented. This method, it is thought, will not only be found highly convenient, but will also greatly facilitate the acquirement of a proper knowledge of chemical equivalents; a subject, as formerly remarked, of great importance to the student in the present state of the science.

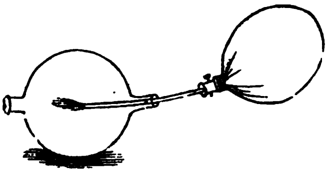
285. **WATER PRODUCED BY THE COMBUSTION OF HYDROGEN.**—It has been stated that water, by analysis, is composed of two parts of hydrogen, and one of oxygen, by volume, and 1 part hydrogen, and 8 oxygen, by weight.

What is signified by the numbers affixed to water, oxygen, and hydrogen? With what does the student become acquainted by observing the numbers affixed to names of the elements, and of their compounds? By analysis, what is the composition of water, by weight and measure?

Having described the properties of these two gases separately, it now remains to demonstrate by *synthesis*, that is, by the combination of these gases, that water is the product.

It may be seen by a very simple experiment, that when hydrogen is burned, water is formed.

FIG. 77.



Combustion of Hydrogen.

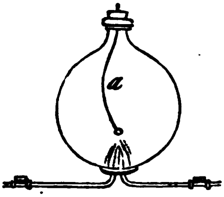
Fill with hydrogen a bladder, furnished with a stop-cock and small tube. Inflame the hydrogen at the end of the tube, and introduce the flame into a dry glass globe with two openings, as represented at Fig. 77. As the gas burns, the rarefied and vitiated air will pass off at one of the openings, while the other admits fresh air to support the combustion. In a few minutes the inside of the globe will be covered with moisture, and by continuing the experiment, water will run down its sides, which may be tasted or otherwise examined. The same experiment may be made with a large glass tube instead of a globe. In this experiment, it is supposed that the combustion of the hydrogen is supported by the oxygen of the atmosphere, and therefore nothing can be known of the proportions in which they unite. Nor would it be absolutely certain by this experiment that it was the oxygen of the atmosphere which combined with the hydrogen, and supported its combustion.

286. Burned in a close vessel.—But when the two gases are confined, each in a separate gasometer, and burned together in an exhausted vessel, the result will not only demonstrate to the senses that water is the product, but will also show the exact proportions of each element by weight and measure.

For this purpose two graduated gasometers contain the two gases, each being furnished with a tube, leading to the glass globe, Fig. 78. Before the experiment begins, this globe is connected with an air-pump, by the screw *c*, and exhausted of air, and then accurately weighed. It is then connected with the two gasometers which contain the gases by the pipes *d*

By what simple experiment may it be shown that when hydrogen is burned, water is formed? Is it absolutely certain by this experiment, that it is the oxygen of the atmosphere which unites with the hydrogen to form water? How may it be demonstrated that the combustion of hydrogen and oxygen form water?

FIG. 78.



Synthesis of Water.

and *e*. When every thing is thus prepared, the stop-cock *d* is opened, and a small stream of hydrogen let in, which is instantly inflamed by an electrical spark from the conductor *a*, this being of course connected with an electrical machine. The oxygen is then admitted, by turning the stop-cock, *e*, and thus the combustion of the hydrogen is supported.

At the end of the process, the graduated gasometers show exactly the volume of each gas consumed, and as the weight of 100 cubic inches of these gases is known, it is easy to compute the weight of the volumes consumed, and, by weighing the globe, to compare it with the weight of water produced.

By such experiments, made with every attention to accuracy, together with that before described, of weighing the gases by means of exhausted vessels, Fig. 65, it is proved, that hydrogen and oxygen unite in the proportions of 2 of the first to 1 of the last, by volume; and in the proportions of 1 and 8, by weight; that the sole product of the combustion of the two gases is water, and that the weight of the water is just equal to the combined weights of the two gases. In this manner has the constitution of water been demonstrated beyond all doubt or controversy.

287. COMPOUND, OR OXY-HYDROGEN BLOW-PIPE.—When the two gases, oxygen and hydrogen, are burned together, or, in other terms, when the combustion of hydrogen is supported by pure oxygen, a most intense heat is the result. This is done by means of the compound blow-pipe, an invention of Dr. Hare, of Philadelphia, about 1801. The apparatus of the inventor has undergone many modifications and improvements, the most recent and complete being represented by Fig. 79. This consists of two sheet copper barrels for holding the gases, the names of each being marked thereon. These are each formed of two cylinders, the one within the other, the usual size being from two to four feet high, and eight or twelve inches in diameter, and holding from 10 to 30 gallons. These contain the water

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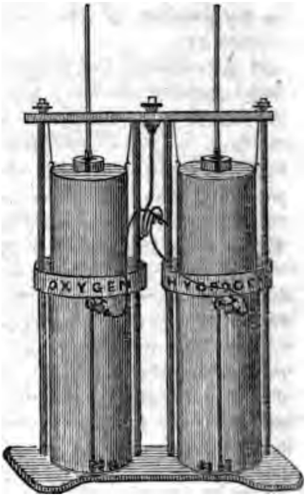
Describe the apparatus represented by Fig. 78, and explain how the two gases are brought together, and how inflamed? At the end of the process, how is it ascertained what proportion of each gas has been consumed, and how much water formed? What is said of the intense heat of the compound blow-pipe?

by means of which the gases are secured, and the pressure for their combustion given by the fall of the upper, and smaller cylinder. Within each of these, is still another cylinder for holding the gases, closed at the bottom, except for the admission of the gas, and open by only a small orifice at the top. These cylinders, besides holding the gas, serve also to diminish the quantity of water required.

FIG. 79.



Compound, or Oxy-hydrogen Blow-pipe.

288. The water is admitted around the inner cylinder, which plays loosely in the outer one, rising and falling as the gas is forced in or pressed out. The posts on each side of the cylinders are hollow, and contain weights by which the upper compartments are sustained, and in consequence of which they press on the gases only when required. The two spindles rising above the cross bar, are continued down into the inner cylinders, and by which they are kept steady as they rise and fall. The tubes of brass seen in front of each, enter the gasometers, being furnished at the top with screws, by which they are connected with the tubes which convey the gases, as each is generated, to its reservoir. The two tortuous pipes of India-rubber, proceeding from these tubes, with which they are connected by stop-cocks, convey the two gases to the burning jet, where their combustion is effected, and the phenomena of the compound blow-pipe exhibited. When additional pressure is required for the emission of the gases from their holders, this is made by slipping on the spindles slit weights of cast iron, as seen in the figure. Connected with this apparatus is a copper bottle holding a pint or more, not seen in the drawing, and

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Give a general account of this blow-pipe, and the method of using it. What is said of its power of consuming the metals, and of its melting the most refractory substances?

which may be screwed to the upper stop-cock of the oxygen holder, and by means of which, with chlorate of potash, and the heat of a spirit lamp, the gas may be at once developed, and conveyed to its proper place.

The stop-cocks seen at the bottom of each gasometer, are for the purpose of letting off the water, whenever this becomes necessary. The tip of the tube for the combustion of the gases is made of platina, this being a slow conductor of heat, and a highly infusible metal.

289. Uses and effects of the blow-pipe.—When the cisterns are filled with the gases, and every thing is ready for their combustion, the stop-cock of the hydrogen is turned, and the issuing gas set on fire. The oxygen is then admitted, when the flame will be diminished to a little jet of bluish light, which to the eye appears quite insignificant, and totally incapable of producing the calorific effects attributed to this celebrated machine. But the student who had never witnessed its effects, will be astonished when he finds that a piece of steel or copper wire, held in this little flame, will burn with a facility equal to that of a cotton thread in the flame of a lamp, and with coruscations of light by which every object in the room will be illuminated. But a still more intense light is produced when a piece of tobacco-pipe is held in the flame, and from the effects of which all present will instantly cover their eyes. The most refractory substances, as platina and the metallic oxides, which have proved infusible by other means, are instantly melted, or dissipated into vapor, by this diminutive flame.

290. Drummond light.—When the flame of the oxy-hydrogen blow-pipe is directed on small masses of prepared lime, the most intense artificial light known is produced. This is known as the Drummond light, the name of the individual who first brought it into useful notice. It has been extensively used as a signal light in our country; and may be seen, it is said, to a greater distance than any other signal during the night.

PROPERTIES OF WATER.

291. It is unnecessary to describe the common properties of a fluid which is so universally known, that neither man nor animal can exist without it. The purest water, not having undergone distillation, is that which falls from the clouds. It is transparent, and without either taste or smell; and being

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Explain what is meant by the Drummond light. What is said of the power and use of this light? What water is purest without distillation?

perfectly bland and neutral, it is to all animals, whose tastes have not been vitiated, the most agreeable of drinks.

292. WEIGHT OF WATER.—The weight of water, as already shown, is the standard by which the weight or gravities of all solids and liquids are estimated. The weight of a cubic foot of pure water is 1000 avoirdupois ounces. A cubic inch of this fluid weighs, at the temperature of 60 degrees, 252.52 grains, and consists of 28.00 grains of hydrogen, and 224.46 grains of oxygen. By dividing 224.46 by 28.06, it may be seen how nearly these gases unite in the proportions of 1 and 8 to form water. The weight of water, when compared with that of air, is as 828 to 1. The effect of temperature upon liquid water is distinguished by a peculiarity of a very striking kind, and exhibits a departure from the general laws of nature, for a purpose so obviously wise and beneficent, as to afford one of the strongest and most impressive of those endless proofs of design and omniscience in the frame of creation, which it is the most exalted pleasure of the chemist, no less than of the naturalist, to trace and admire.

293. WATER EXPANDS IN FREEZING.—All liquids, except water, contract in volume as they cool down to their points of congelation; but the point of the greatest density in water is about 40 degrees, its freezing point being 32 degrees. As its temperature deviates from this point, either upward or downward, its density diminishes; or, in other words, its volume increases. This peculiar law is of much greater importance in the economy of nature than might at first be supposed. The cold air which rushes from the polar regions progressively abstracts the heat from the great natural basins of water, or lakes, till the whole mass is reduced to 40 degrees; but at this point, by a wise Providence, the influence of the atmosphere no longer has this effect; for the superficial stratum, by further cooling, becomes specifically lighter, and instead of sinking to the bottom, as before, and displacing the warmer water, it now remains at the surface, becomes converted into a cake of ice, and thus preserves the water under it from the influence of further cold.

If, like mercury, water continued to increase in density to its

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To what animals is water the most agreeable of all drinks? What is the weight of a cubic foot of pure water? What is the weight of a cubic inch of water? How may it be proved that the weights of hydrogen and oxygen in water are in the proportions of 1 to 8? What is the weight of water when compared to that of air? At what temperature is water at its greatest density? When water is above or below the temperature of 40 degrees, how is its bulk affected? In what respect is the expansion of water in freezing of great consequence to man?

freezing point, the cold air would continue to rob the mass of water of its heat, until the whole sunk to 32 degrees, when it would immediately congeal into a solid mass of ice to the bottom, and thus every living animal it contained would perish. In the northern or southern temperate zones, such masses of ice would never again be liquefied; a striking proof of the beneficence and design of the Creator in forming water with such an exception to the ordinary laws of nature.

294. **Water contains air.**—Water, in its natural state, always contains a quantity of air. This may be shown by placing it under the receiver of an air-pump, for as the air is removed from the receiver, bubbles will be seen to rise from the water. The air in water is found to contain a larger proportion of oxygen than the common air of the atmosphere. The lives of all such fishes as live entirely under the water, depend on the quantity of oxygen it contains, for no animal can live and move where oxygen does not exist.

GASES ABSORBED BY WATER.

295. Although water contains a considerable quantity of air in its natural state, amounting, according to the experiments of Mr. Dalton, to 2 cubic inches to 100 inches of the fluid, it yet absorbs some of the artificial elastic fluids with great avidity, and a few of them in large quantities. Before exposure to the gases mentioned below, it was, however, deprived of all aeriform matter, by long boiling.

The table exhibits the quantity of each gas absorbed at the mean temperature and pressure of the atmosphere:

Gases.	100 volumes of water absorb volumes of	Authority.
Oxygen	3.7	Dalton.
Chlorine	200	Gay Lussac.
Hydrogen	1.56	Henry.
Muriatic acid	50.000	Davy.
Nitrogen	1.56	Henry.
Nitrous oxide	100	Henry.
Nitric oxide	5	Brande.
Ammonia	67.000	Brande.
Sulphuric acid	3.000	Davy.
Sulphureted hydrogen	100	Dalton.
Carbonic acid	100	Dalton.
Carbureted hydrogen	12.5	Gay Lussac.

If water, like mercury, had its density increased by cold to 32 degrees, what would be the consequence on large bodies of this fluid? What is said of the beneficence and design of forming water with this exception to the ordinary laws of nature? How is it shown that water always contains air? How does the air in water differ from common air?

DEUTOXIDE OF HYDROGEN.

Equivalent, 17. Symbol, HO_2.

2 eq. Oxygen, 16+1 eq. Hydrogen, 1.

OXYGENATED WATER.

296. Water, in the scientific language of chemistry, is the *protoxide of hydrogen;* being composed of hydrogen, with one proportion of oxygen. (*See Nomenclature.*) It was supposed that hydrogen was incapable of a further degree of oxygenation, until 1818, when Thenard, a French chemist, showed that by a certain intricate process, hydrogen could be made to combine with another dose of oxygen, and thus a new compound was formed, called *deutoxide* of hydrogen.

This compound is formed in precise accordance with the law of definite and multiple proportions, and consists of 2 proportions of oxygen and 1 of hydrogen, as stated at the head of this section. It is a highly curious and interesting compound. In some of its properties it exactly resembles water, being inodorous and colorless; but in others, it is remarkably different. It is corrosive to the skin, which it turns white, and to the tongue it is sharp and biting, and leaves a peculiar metallic taste in the mouth.

At the temperature of 58 degrees, it is decomposed, oxygen gas being evolved in abundance. It is therefore necessary, in the summer season, to keep it surrounded with ice. It is also decomposed and turned into common water by nearly all the metals, and most rapidly by those which have the strongest attraction for oxygen. Some of the metallic oxides produce the same effect, without passing into a higher degree of oxidation, a fact which has not been satisfactorily explained. The metals, silver and platinum, in a state of fine division, decompose this water, when thrown into it, with such energy as to produce explosions. The same effect is produced by the oxides of silver, gold, mercury, manganese, and several other metals.

NITROGEN.

Equivalent, 14. Symbol, N.

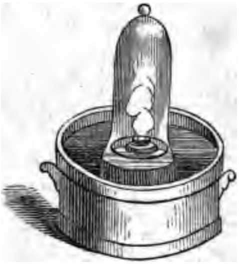
297. This gas was formerly called *azote*, which signifies *life*

What is the scientific name of water? What is the deutoxide of hydrogen? What are the properties of oxygenized water? How does this compound differ from common water? At what temperature is this compound decomposed? Why do the metals decompose this kind of water? and what do they absorb from it? What was the former name of nitrogen? What does azote signify?

destroyer, because no animal can live when confined in it. But the same epithet might be applied to several other gases, with equal propriety; and therefore, being the basis of nitric acid, it is more properly called *nitrogen*. As the atmosphere is composed of four-fifths of nitrogen, this gas may be obtained by placing a mixture of iron filings and sulphur, a little moistened, in a confined portion of air, as under a bell glass, over water. The mixture will absorb the oxygen from the air, and leave the nitrogen nearly pure.

298. BY PHOSPHORUS.—A more speedy method of obtaining nitrogen is by the combustion of phosphorus in a close vessel. This is done as follows: In a dish of shallow water place a piece of wood, or cork, Fig. 80, and on this put a piece of phosphorus weighing ten grains or more, according to the quantity of gas desired. Have ready a bell glass, and having touched the phosphorous with a hot iron, immediately invert the receiver over it into the water. A few bubbles of air will escape, owing to the expansion of the heat, after which, as the phosphorus consumes, phosphoric acid will be formed by its union with the oxygen of the air within the vessel, which acid will be absorbed by the water, leaving the nitrogen nearly pure in the receiver.

FIG 80.



Production of Nitrogen.

It is destructive to animal life, and is a non-supporter of combustion. A lighted candle plunged into it, is instantly extinguished, and any animal soon dies when confined in it. Yet it exerts no injurious influence on the lungs, the privation of oxygen being the sole cause of death.

Its specific gravity is a little less than that of atmospheric air, nitrogen being 0.9722, air being 1000. One hundred cubic inches weigh 29.7 grains.

When combined with oxygen in certain proportions, it forms nitric acid. Nitrogen exists in all animal substances, and in

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Why is it now called nitrogen? How may nitrogen be obtained? How is gas obtained by means of iron filings and sulphur? How is nitrogen obtained by means of phosphorus? In what manner does nitrogen destroy life? Is the specific gravity of nitrogen greater, or less than that of atmospheric air? With what substance does nitrogen form nitric acid?

such plants as putrefy with an animal odor, as cabbage and mushrooms.

COMBINATION OF OXYGEN AND HYDROGEN.

299. It has already been stated that when oxygen and hydrogen are burned together, the product is water. We have also pointed out a method of making this experiment, but the more simple and elegant plan of Prof. Mitscherlich, of Berlin, is the following:

The exact proportions in which these gases combine to form water, are two of hydrogen and one of oxygen, and in consequence of this combination, the volume is diminished 2000 times, that is, the water takes up 2000 times less space than did the gases.

In order to make this experiment with exactness, the gases must be quite pure. The oxygen, when obtained by means of chlorate of potash, is of sufficient purity; but the hydrogen, when evolved by means of zinc and acid, contains impurities, probably sulphurous acid gas, and must therefore be passed through a solution of potash, in order to make it fit for the experiment.

300. Apparatus.—For the above purpose, the simple apparatus, Fig. 81, may be employed. Or a similar one may be readily constructed by means of two wide mouthed vials, bent glass tubes, and corks.

This apparatus consists of the larger bottle, having the cork pierced with two apertures for the admission of the two tubes, of which *a* is for the introduction of the sulphuric acid, and *e*, *f*, for the escape of the gas. The granulated zinc being first placed in the bottle, the acid is poured in by the widened tube at *b*, when the gas thus produced, rises and passes the tube, *f*, into the second bottle, to the bottom of which the tube dips, through a solution of potash. The gas thus rising through this solution, passes through the tube leading to the gasometer in a purified state. The hydrogen thus purified is ready for use by means of the apparatus next to be described. This consists of a glass cistern, *c*, Fig. 82, for holding the mercury; a graduated tube, *a*, for the gases; a support to keep this tube from falling; and a charged Leyden jar, coated inside and out, together with a chain as a conductor. The tube is graduated by means of a small vessel, which is to be filled with mercury,

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In what vegetables is this gas found?

FIG. 81.

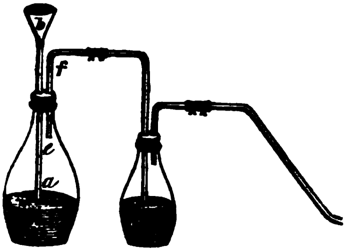
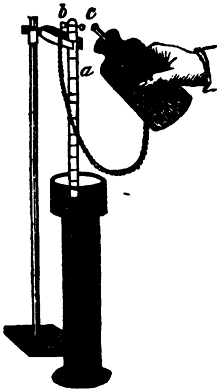


FIG. 82.



Proof of the Composition of Water.

and poured into it. The quantity is to be definite, say a square inch, being the capacity of the cup, so that we know by the number of times the cup-full is poured in, how many square inches of bulk the tube contains. The tube being thus filled, is inverted in the mercury, as represented in the figure. Then allowing the oxygen to enter at the lower end of the tube, its quantity is exactly ascertained by the fall of the mercury, as indicated by the markings on the tube, each mark being equal to a square inch, or a cup full of the mercury. Having admitted the oxygen, the hydrogen must be allowed to enter in small quantities at a time, to prevent explosion. The manner of ignition by this apparatus is quite simple. The tubes, being pierced near the top, pieces of platina or iron wire are inserted, their points coming within striking distance, inside the tube. Then, having charged the vial, hold the chain in contact with the foil on the outside, the other end of the same being fastened to one of the wires which enter the tube, as seen at *b*. Now touch the other wire, *c*, with the brass nob, connected with the inside of the charged jar, and it is plain that the electric fluid, in passing from the positive to the negative side of the jar must pass from the point of one of the wires to that of the other, within the tube, and thus the hydrogen is inflamed, its combustion being supported by the oxygen.

As the gases are consumed, the mercury will rise in the tube, showing exactly what number of cubic inches disappear, and also what quantity of water they form.

If more than twice the quantity of hydrogen, than there is of the oxygen, is admitted, it will remain in the tube unconsumed, and so, on the contrary, if the oxygen is more than half the bulk of the hydrogen, it will remain pure oxygen.

CHAPTER XV.

THE ATMOSPHERE.

301. Composition.—The air which we breathe is composed of 20 parts of oxygen, and 80 parts of nitrogen, to every hundred by volume.

These proportions are found never to vary, except from local causes. Gay Lussac, in an aerial voyage, carried with him an exhausted bottle, closely corked, and when at the height of nearly 22,000 feet from the earth, he uncorked his bottle, and let in the air. It was then closely corked again, and brought to the earth. On examination, this air was found to contain precisely the same proportions of the two elements as that taken from the surface of the earth. Specimens of air have also been brought from Chimborazo, Mount Blanc, from the deserts of Africa, and from the midst of the oceans, and on analysis, they have all been found to contain the same proportions of the two gases.

These proportions are found by experiment to form the most agreeable air for respiration, and to be best fitted for the support of animal life. Animals confined in air, containing more than the ordinary proportion of oxygen, have their respiration hurried, and become feverish, by over excitement; while those confined to air which contains a less proportion of that gas, become languid and faint, from the want of its stimulating effects.

302. Contains carbonic acid.—Besides these two gases, the atmosphere contains variable portions of carbonic acid gas,

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What is the composition of atmospheric air? What is said of the constancy of these proportions? From what parts of the world have specimens of air been analysed, and found to contain the same proportions of the two gases? What is the effect of a greater proportion of oxygen than common air contains on the animal system? What is the effect of a less proportion on the system? Does the atmosphere contain other gases besides oxygen and nitrogen?

and aqueous vapor. The carbonic acid seems always to be present, since Saussure found it in the air of Mount Blanc, taken from the height of 16,000 feet above the level of the sea. Its proportion never exceeds one part in a 100, in freely circulating air; and it generally amounts to only 1,1000th or 1,2000th part of the whole. The proportion of aqueous vapor is also exceedingly variable, but seldom exceeds 1 part in 100.

The air of particular situations is also found to contain small quantities of carbureted hydrogen, or inflammable gas, and of ammonia; but these are not constant.

303. THE ATMOSPHERE A MIXTURE.—It has been a question among chemists, whether the two gases composing the atmosphere are simply in a state of mixture, or whether they exist in a state of chemical combination. Mixture has commonly been distinguished from combination, by the spontaneous separation of the ingredients of the former. But, although oxygen is specifically heavier than nitrogen, no such instance has been found to occur.

Air, confined in a long tube standing vertically for many months, was found to contain the usual proportion of oxygen in its upper part. The proportions of its constituents are also definite, like those of energetic combinations. By weight, there are two proportions of nitrogen, 28, with 1 of oxygen, 8. And by volume, 4 parts of the first, 80, to one of the latter, 20, in the 100, thus making the simple proportions of 4 to 1.

It has, however, been found that other gases, of different specific gravities, mix with entire uniformity where it is known that no chemical union exists between them. Thus, if one vessel be filled with carbonic acid gas, and another with hydrogen gas, the latter being placed over the former, with a tube communicating between them, the two gases will mix with perfect uniformity in a few hours. In this instance, a part of the carbonic acid, though 22 times as heavy as the hydrogen, is found to have ascended into the upper vessel, while a part of the hydrogen, though 22 times lighter than the acid gas, descends into the lower one. The cause of such an intimate mixture, under such circumstances, and without the influence of chemical attraction, has not been explained. But the fact is

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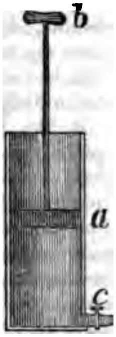
What other gas is always found in the air? What gases are occasionally found, their presence depending on local circumstances? What reasons are there to believe that air is a chemical compound? What singular fact is mentioned in respect to the mixture of carbonic acid and hydrogen through a tube? What does this fact show with respect to the uniform mixture of the elements of the atmosphere without a chemical union?

sufficient to show, that the uniform mixture of the constituents of the atmosphere may be accounted for, without a chemical union. The facility, also, with which oxygen is abstracted from the atmosphere, is against a chemical union. Thus, rain-water contains a considerable portion of oxygen, besides a portion of atmospheric air. But the attraction of water for oxygen is not supposed sufficient to overcome a chemical combination, and therefore did such a combination exist in the atmosphere, oxygen would not be found in water under such circumstances.

304. Elasticity and weight of the atmosphere.—By *elasticity*, when applied to a fluid, is meant that it has the property of regaining its original volume after compression. In proof of this, we have only to force down the piston of a syringe, or even pop-gun, when, as every one knows, the confined air resists such force, and instantly springs back to its original volume when the pressure is removed. No matter how great the pressure may be, or how long continued, the air will instantly assume its former state when the force ceases.

FIG 83.



Elasticity of Air.

If the stop-cock at the bottom of the cylinder, Fig. 83, be closed, and then the piston be drawn up, it will be found that considerable and increasing force is necessary for this purpose, because the weight of the atmosphere from above resists the rise of the piston from the bottom of the cylinder. At the same time, the air within the cylinder, by its elasticity, expands and fills the space in the cylinder, which otherwise would be a vacuum, or void space.

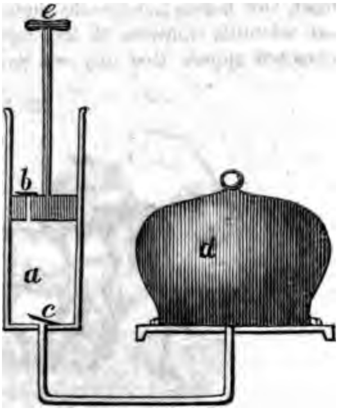
If, on the contrary, the cylinder is opened at the bottom, the piston can be drawn up with ease, because the air is then allowed to enter below it, and thus to balance the weight of the atmosphere from above. But if the aperture be closed when the piston is half way up the cylinder, and then the attempt be made to force the piston down, it will be found that the air within will resist against all such attempts, and by its elasticity will drive the rod against the hand with a force proportionate to that with which it was driven downward, or the air compressed.

What does the facility with which oxygen is abstracted from the atmosphere tend to show in respect to this chemical union? How is it shown that the air possesses elasticity and weight?

Thus, by very simple experiments, and with an apparatus which almost any one can make for himself, we may become convinced that the air has both weight and elasticity, two properties of great importance; and although tested at the present day with such ease, were still unknown to ancient philosophers, having not been discovered until the 16th century, as will be shown as we proceed.

305. Air-pump.—This, it is well known, is an instrument by means of which the air can be exhausted from a close vessel. The *principle* of the air-pump will be understood by inspecting Fig. 84, in connection with the following description. The figure is modified from Fawne's, and consists of the metallic cylinder *a*, with its piston, and valve opening upward, *b*; the cylinder valve, also opening upward, *c*, which is connected with a tube leading to the interior of the vessel to be exhausted, called the ***receiver***, ***d***; and the handle of the piston rod *e*, by which the piston is worked.

FIG. 84.



Air-pump.

The *action* of so simple a machine is readily understood. Suppose the piston to be at the bottom of the cylinder, both valves, of course, being closed. Now, on drawing it up, the valve *b* opening upward will remain closed, and below it there would remain a void space, did not the valve *c*, open and admit the air through the tube from the receiver. This happens because the air in *d* expands by its elasticity, to fill the space left by the piston in the cylinder. Then, on the descent of the piston, the valve *b* will open, while *c* will close, and thus a portion of the air from the receiver will escape as before. Thus, at every rise of the piston a cylinder full of air is removed, the space left being again filled by the expansion of that in the vessel *d*, until this becomes so

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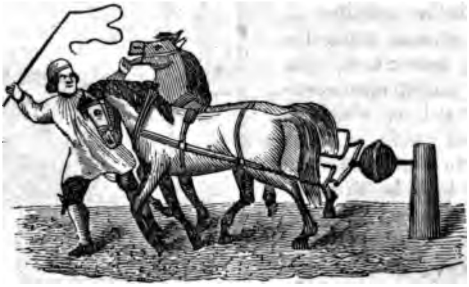
Give a description of the air-pump, Fig. 84.

exhausted as no longer to be capable of opening the valves, when the operation must cease. It will be observed, therefore, that a perfect vacuum can not be effected by the air-pump, since there must always remain sufficient resistance in the air within the receiver and cylinder to open the valves, otherwise the machine will not act.

306. THE MAGDEBURG HEMISPHERES.—The famous experiment made by Otto von Guericke, a magistrate of Magdeburg, who invented the air-pump, in 1652, consisted in forming a vacuum within a hollow ball made of two halves, which then adhered together with such force as to require, it was said, at least, two horses to separate them. This was among the greatest scientific wonders of the age, since before that period, it does not appear that any one had ever conceived it possible to exhaust a vessel of its air by pumping, or had imagined its effects, if it could be done. If we suppose these hemispheres to to have been made of copper, or iron, the one entering the other an inch or two, with a flange, and then both ground together with emery, it is quite easy to conceive that they might have been made perfectly air-tight, though completely exhausted of air. The manner in which a common snuff-box, without hinges, is put together, will illustrate the way in which these hemispheres are fitted to each other. When filled with air, or under ordinary circumstances, they would not adhere so that one would lift the other, but when exhausted of air they

FIG. 85.



The Magdeburg Hemispheres.

What is said of the Magdeburg hemispheres? How were they formed and put together?

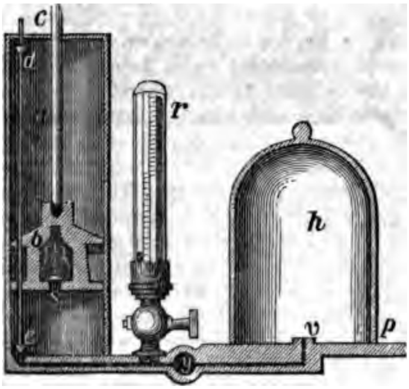
were pressed together with a force equal to 15 pounds to every square inch of surface.

The Magdeburg experiment, which seems to have formed an era in pneumatic philosophy, has been mentioned in every treatise on the air-pump from the time it was performed to the present. As a curiosity for our young students, we have taken this occasion, therefore, to illustrate the subject, with the horses attached to the hemispheres, in the manner it is said to have been originally performed.

If we consider the hemispheres to have been equal to a square foot in extent, then the surface of one side would be equal to 12×12, or 144 square inches. The pressure of the atmosphere, as above stated, is equal to 15 pounds to the square inch, and therefore the whole pressure opposed to the horses would have been 144×15=2160, or about one tun; a light draught, indeed, for a pair of horses, but sufficient to excite wonder at a time when the force they had to overcome was not only unseen, but mysterious.

307. **German air-pump.**—It will be seen that this instrument is quite different in some of its parts from the common air-pump, or that usually described and employed in this country. In some respects it no doubt presents improvements on

FIG 86.



German Air-pump.

Give some account of the German air-pump, and explain how it differs from the common air-pump.

the common form, and as its construction appears to be sufficiently simple, and the book from which it is derived is not very common, it may perhaps become a source of improvement. In the cylinder, *a*, Fig. 86, the piston, *b*, must move perfectly air-tight, and the piston rod, *c*, must also move without loss of air through its stuffing. In the piston, the valve *s*, opens easily upward, rising when the pressure from below is greater than from above. The rod, *e*, *d*, opens and shuts the valves of the cylinder, or rather its two conical ends form substitutes for the two valves in question. This rod passes through a side of the piston, and passing with friction, is raised to close the orifice, *d*, in the upper part of the cylinder when the piston is elevated, and when the piston moves downward, *d*, is opened, and the orifice *e*, leading to the bell glass *v*, is closed. Thus, at every stroke of the piston a portion of air is let into the cylinder from the receiver *h*, through the orifice *e*, and from the cylinder into the open air through the aperture *d*. In the middle of a smooth table of brass called the *plate p*, opens the canal *v*, leading to the cylinder, and by means of which the receiver is exhausted by the action of the piston. The action being precisely like that already explained, when treating of the *principle* of the air-pump, it will be unnecessary to repeat this part of the subject.

At *r*, is a long, narrow bell glass, or wide tube, containing a short mercurial barometer, which being connected with the canal from the cylinder to the receiver, will show at once, by turning the stop-cock with which it is provided, the amount of atmospheric pressure, or the degree of exhaustion which the receiver has suffered.

308. CONSUMPTION OF OXYGEN.—The oxygen of the atmosphere being the principle which supports life and flame, it is obvious that large quantities of this gas must be consumed every day, and therefore that its quantity must diminish, unless there exists some source from which it is replaced. The quantity consumed, however, must be exceedingly small, in a definite period of time, when compared with the whole; for the atmosphere not only entirely surrounds the earth, but extends above it, at every point, about 45 miles. Now, when we consider how small a proportion of this immense mass comes into contact with animals or fires at any one time, and that it is only these small portions that become vitiated, we may suppose

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What is said of the quantity of oxygen consumed by animals and flame, when compared with the whole which exists in the atmosphere?

that ages would elapse before any difference could be detected in the quantity of oxygen, even were there no means of replenishment provided.

But the wisdom and design of Deity, which the study of nature every where detects, and which as constantly seems ordained for the benefit and comfort of man, has not left so important a principle as that of vital air to be consumed, without a source of regeneration.

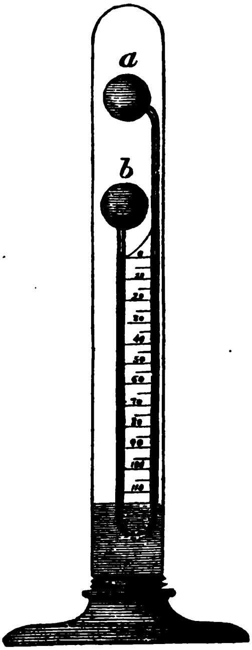
309. **Vegetation the source of oxygen.**—It appears from experiments, that vegetation is the source from which the atmosphere is replenished with oxygen, and so far as is known, this is the only source. Growing plants, during the day, absorb carbonic acid from the atmosphere, decompose the gas, emit the oxygen of which it is in part composed, and retain the carbon to increase their growth. (*See Vegetation.*)

We have seen, under the article *Oxygen*, that when wood or carbon is burned, that oxygen is thereby converted into carbonic acid gas, and a greater or less proportion of this gas contained in the atmosphere may be attributed to this source. Here, then, we are able to trace another instance of the wonderful order and design of Omnipotence. The destruction of plants by burning, while the process absorbs the oxygen from the air, furnishes carbonic acid, which, in its turn, is decomposed by growing vegetables, the carbon being again converted into wood, while the oxygen goes to replenish the loss created by the burning, and to purify the atmosphere for the use of man.

310. **Light.**—All the light which the sun sends to the earth is transmitted through the atmosphere, and as this becomes translucent by the presence of fogs or clouds, or perfectly transparent by the absence of all such impediments, so in proportion is the light and heat of the sun diminished or increased. Now all have observed the difference between the heat and light of the sun at different seasons of the year, and even on different days of the week, but it is known to comparatively few, that there exists an instrument by which the different quantities, or degrees of light can be measured or indicated. This instrument is Leslie's photometer, or "*light measurer*," a figure and description of which are annexed.

From what source is the atmosphere replenished with oxygen? How do plants obtain the oxygen which they emit? Whence comes the carbonic acid gas which plants decompose? What is said of the wonderful order and evident design of Providence, in making the destruction of plants the means of replenishing the air with oxygen?

FIG. 87.



Leslie's Photometer.

311. **Photometer.** — Leslie's portable photometer, Fig. 87, consists of two glass balls, one above the other, with a graduated tube between them. The upper ball, *a*, is of black glass, in consequence of which it absorbs the greatest quantity of heat; the lower one, *b*, is made as diaphanous, or transparent as possible, so that it will transmit, as nearly as may be, all the light and heat which falls upon it. It will be observed that the degrees, in this instrument, are on the descending scale, the height of the alcohol, with which the tube is filled, being depressed by the expansion of the air in the upper ball.

The theory of this instrument is founded on the principle that the intensity of the light is in exact proportion to that of the heat, the incident rays of which expand only the air in the black ball, while they both pass through the diaphanous, or lower one, without obstruction, and consequently without effect, though both are equally exposed in the open air, to the light and heat of the sun. In England, Mr. Leslie found that the direct rays of the sun forced the liquid down to 90 or 100 degrees, on the hottest days of summer, while the warmest rays of winter at noon, only showed a depression of 25 degrees. The indirect light of the sky, as when the sun was obscured at noon in summer, is from 30 to 40 degrees, and in winter from 10 to 15 degrees.

Comparing the illuminating power of the sun with that of artificial light, it was estimated by Leslie that his light was equal to that of 12,000 wax candles.

This curious instrument, as already stated, is easily constructed, being exactly like the differential thermometer, only

Give a description of Leslie's photometer.

that the tube is bent in a different manner. It may be a foot high, and filled with stained alcohol.

PROTOXIDE OF NITROGEN.

Equivalent, 22. Symbol, NO.

1 eq. Nitrogen, 14 × 1 eq. Oxygen, 8.

NITROUS OXIDE.

312. The best method of obtaining this gas is by fusing a salt called *nitrate of ammonia.* This salt may be readily formed by mixing carbonate of ammonia with nitric acid, (aqua fortis,) diluted with four or five parts of water, and then evaporating the solution by a gentle heat. The ammonia should be added in small lumps until the effervescence ceases; and the evaporation continued until a drop of it, placed on glass, concretes.

Having prepared the salt, the nitrous oxide, or *exhilerating gas*, may be procured from it, and its effects by respiration tried by the following simple means, when no better apparatus can be obtained.

Prepare a Florence flask, as shown at Fig. 54, and into this put four or five ounces of the nitrate of ammonia. For a gas-holder, fit to a large stone-ware jug a cork pierced with two apertures with a burning iron; into one of the apertures pass a tube of glass, or tin, so that it shall reach nearly to the bottom when the cork is in its place, and stop the other orifice with a cork.

For a pneumatic cistern, take a common wash-tub, and fit to it a strip of board passing through the middle, and about four inches from the top, so that when the tub is filled with water, the board will be covered. Through the board cut a hole to receive the neck of the jug, so that it will stand inverted.

Having prepared things in this manner, fill the jug with water, and invert it into the tub, also previously filled with water. Then bend the tube belonging to the flask, so that it will enter the mouth of the jug, while the flask itself stands on a ring of the lamp furnace, and apply a gentle heat.

If no lamp furnace is at hand, the flask may be suspended by a wire or string, and heated by a common lamp, or a few coals.

What do these compounds illustrate? What is the signification of protoxide? What other name is there for protoxide of nitrogen? How is this gas obtained? How is nitrate of ammonia formed? Having prepared the salt, in what manner is the gas extracted from it? In what manner may a temporary gas-holder and water bath be prepared? Having prepared the gas-holder, or jug, and the water bath, or tub, how will you proceed to fill the jug with gas? How will you know when the jug is full of gas?

The salt will soon melt and become fluid and transparent, when the gas will be extricated in abundance. When the jug is nearly full, which will appear by the sound of the bubbles, slip the hand under its mouth, and having set it upright, immediately put the cork, with the tube through it, in its place. As the nitrous oxide sometimes contains a mixture of nitric oxide, or *binoxide of nitrogen*, which is dangerous to respire, but which is absorbed by water, it is safest, before the gas is respired, to let it stand an hour or two, with the water remaining in the jug.

To respire the gas, prepare a bladder, or oiled silk bag, by attaching to it a tube which fits closely to the second aperture in the large cork, and having squeezed all the air out of the bladder, or bag, remove the small cork, and pass in the tube.

Next pour such a quantity of water into the jug, through the long tube, as it is desired to obtain gas in the bag. Now, the gas can not escape through the long tube, because its lower end is in the water, nor can it escape through the mouth of the jug, this being closed by the cork; it therefore passes into the bag. When this is full, withdraw the tube from the jug, and having expired, or thrown the air from the lungs, close the nose with one hand, and with the other apply the tube to the lips and breathe the gas from the bag into the lungs, and from the lungs to the bag. Sir H. Davy respired 12 quarts, but the medium dose is from 4 to 8 quarts for an adult.

313. EXHILERATING EFFECTS.—On some persons this gas has a highly exhilerating or intoxicating effect, and produces the most agreeable sensations, often attended by momentary mental hallucinations and corresponding actions. On others, it produces mental depressions, and melancholy forebodings. Its action commonly continues only for a few moments, and its effects seldom or never produce a state of languor, or debility, which might be expected to follow such a degree of excitement.

314. COMPOSITION.—The composition of the protoxide of nitrogen by volume, is nitrogen 100, and oxygen 50. 100 cubic inches of this gas weighs 46.5 grains, and its specific gravity is, therefore, 1.5, air being 1. It is transparent, and colorless, has a sweetish taste, and an agreeable aromatic smell. It is a supporter of combustion, and many substances burn in it

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What gas is sometimes mixed with the nitrous oxide? Why is it safest to let the gas stand over water awhile before it is breathed? After having prepared a bladder, or gas bag, how is this filled with the gas from the jug? How is the gas respired? What is the medium dose for an adult? What effect is the respiration of this gas said to produce on the human feelings? What is the composition of the nitrous oxide? What is its specific gravity? Does this gas support combustion?

with far greater energy than in atmospheric air. The burning body absorbs the oxygen from the nitrous oxide, and thus the nitrogen remains in the vessel.

BINOXIDE OF NITROGEN.

Equivalent, 30. Symbol, NO_2.

1 eq. Nitrogen, 14+2 eq. Oxygen, 16.

NITRIC OXIDE. NITROUS GAS.

315. Binoxide of nitrogen, as expressed above, and as its name signifies, contains two proportions of oxygen to one of nitrogen. It was formerly called *nitric oxide*, and *nitrous gas*. but analysis having shown its composition, its name is fixed in accordance. This gas is formed by the action of nitric acid on copper. Having introduced some copper turnings, or filings, into a retort, pour on them a quantity of strong nitric acid, or aqua fortis. A violent effervescence will ensue, and the gas will escape in abundance. At first it will appear of a deep red color, which is owing to the presence of atmospheric air in the retort; but on passing it through water the red fumes are absorbed, and the nitrous gas remains pure and colorless.

316. CHEMICAL CHANGES.—To understand the chemical changes by which this gas is formed, it is necessary to state that nitric acid is composed of 40 parts of oxygen and 14 parts of nitrogen, and that this acid is decomposed by the process. A part of the oxygen of the acid unites with the copper, and forms an oxide of the metal, while another part of the oxygen continues in union with the nitrogen, forming a binoxide of nitrogen, which, as already seen, contains only 16 parts of oxygen. The gaseous form of the binoxide is owing to the absorption of a quantity of caloric at the instant of its formation. The evolution of this gas is therefore owing to the abstraction of a part of the oxygen from nitric acid, by the copper. Other metals, and particularly quicksilver, will produce the same effect.

Nitrous gas, when pure, is sparingly absorbed by water. It is a little heavier than atmospheric air, 100 cubic inches weighing 31.7 grains, while the same quantity of air weighs 30.5 grains. It can not be respired, even in small quantity, without

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What does binoxide signify? What is the composition, and what the equivalent numbers for binoxide of nitrogen? What was the former name of this gas? How is nitric oxide obtained? Why do the first portions of this gas appear red? What are the chemical changes by which this gas is formed? What causes the gaseous form of this acid? To what is the evolution of this gas owing? What is the weight of this gas?

a sense of suffocation, and violent coughing. It instantly extinguishes the flame of most substances, when plunged into it; but if charcoal, or phosphorus, in a state of vivid combustion, be immersed in it, its oxygen is absorbed, and they burn with increased energy.

When mixed with atmospheric air, red fumes are generated, as already noticed. This is owing to the union of the oxygen of the atmosphere with the nitrous gas. When pure oxygen is added to a portion of this gas, the red becomes still deeper, and there is formed nitrous acid, which is entirely absorbed by water. Thus these two gases, nitrous gas and oxygen, are a delicate test for each other, the smallest quantity of the one being detected by introducing a quantity of the other.

317. EUDIOMETRY.—From the property of the nitrous gas above stated, it has been employed in ***Eudiometry***, that is, to ascertain the purity of the atmosphere, or the quantity of oxygen it contains.

The method by which this is done, is to confine a certain portion of air in a graduated tube, and then to introduce into the tube a sufficient quantity of the gas to unite with all the oxygen it contains. Then, as the compound formed between the oxygen and the nitrous gas is entirely absorbed by water, it is readily seen by the graduated tube what proportion of air has disappeared, after agitating the mixture with water, and consequently how much oxygen it contained.

318. COMPOSITION.—The composition of binoxide of nitrogen has been accurately ascertained by burning charcoal in it, which absorbs all the oxygen, amounting to exactly one-half the volume of the whole, and leaves the nitrogen, which amounts to the other half. By this analysis it is found, that 100 parts of this gas lose 50 parts of oxygen, and that 50 parts of nitrogen remain.

50 cubic inches of oxygen weigh	16.8 grains.
50 cubic inches of nitrogen weigh	14.9 grains.
The 100 parts, therefore, weigh	31.7 grains.
The equivalent composition, therefore, is 1 atom, or equivalent of nitrogen,	14
2 " " oxygen,	16
	30

What are its effects on respiration and flame? What acid is formed when this gas combines with an additional portion of oxygen gas?

PEROXIDE OF NITROGEN.

Equivalent, 46. Symbol, NO_4.

1 eq. Nitrogen, 14 + 4 eq. Oxygen, 32.

NITROUS ACID.

The next compound of nitrogen and oxygen which we shall notice is nitrous acid.

319. How obtained.—This acid is formed by adding oxygen to the compound last described, in consequence of which the nitrogen of that compound combines with another portion of oxygen equal to that which it before contained. The deutoxide contained 2 proportionals of oxygen, 16. The nitrous acid contains 4 proportionals of oxygen, 32. Between these, there is a hypothetical compound, containing 3 proportions of oxygen, but which has not been obtained in a free state. This is called *hyponitrous acid*, and by some subnitrous acid, because it contains less oxygen than nitrous acid.

Nitrous acid may also be obtained by the distillation of nitrate of lead, in a retort. (*See Nitrate of Lead.*) During the distillation, the receiver should be kept cold, by surrounding it with ice.

By either of these methods, there is obtained a vapor, or gas, of a deep orange red color, which is the nitric acid in a gaseous state. To obtain it pure, it is, however, necessary that the receiver should be first exhausted by the air-pump, because the gas is instantly absorbed by water, and a mercurial bath can not be employed, because the gas acts upon that metal.

By volume this acid is composed of,

Nitrogen,	100	By weight, Nitrogen,	14
Oxygen,	200	" " Oxygen,	32
	300		46

Nitrous acid, in its fuming state, is totally irrespirable; but supports the combustion of phosphorus, or charcoal, when these are introduced into it in a state of combustion.

By what fluid is this gas absorbed? In what manner is the nitrous gas employed to ascertain the quantity of oxygen in the atmosphere? In what manner has the composition of this gas been ascertained? What is the composition of this gas? What is its equivalent number? What are the equivalent numbers of its elements? What are the processes by which nitrious acid may be obtained? What is the composition of this acid? In what does this acid occur, and what is its color? How is this acid obtained in its pure state? Why can not a mercurial or water bath be employed to confine this gas? What are the definite proportions of the elements of this acid by volume and weight? Does this gas support combustion, or animal life?

Water absorbs this gas in large quantities, and acquires thereby, first a green, and afterwards a blue tint. If still more be added, it becomes yellow, or colorless, and forms a solution of nitrous acid in water.

NITRIC ACID.

Equivalent, 54. Symbol, NO_5.

1 eq. Nitrogen, 14 + 5 eq. Oxygen 40.

AQUA FORTIS.

320. If a mixture of oxygen and nitrogen be confined in a glass tube containing a little water, and powerful electrical shocks be passed through this mixture, the water, after a continued succession of such shocks, will possess acid properties. By this process, the two gases are made to combine and form nitric acid, which is absorbed by the water.

This experiment is designed merely to prove that the acid in question is formed of oxygen and nitrogen.

321. HOW OBTAINED.—The usual mode of forming this acid is, by the distillation of the *nitrate of potash*, more commonly called *nitre*, or *salt-petre*, with sulphuric acid. The proportions are four parts of nitre, in coarse powder, with three parts of the acid by weight. The receiver must be large, and kept cold, otherwise much of the acid will escape before it is condensed. The strongest acid is formed when no water is placed in the receiver, that already combined with the sulphuric acid being sufficient to condense the nitric acid vapor as it is formed.

The strongest nitric acid is without color, and has a specific gravity of 1.5, that is, this acid is by one-half heavier than water. In this state it contains 25 per cent. of water.

The dry nitric acid, which is formed by the condensation of its constituent gases, contains no water, and is composed, as stated at the head of this section, of 1 proportion of nitrogen, 14, and 5 proportions of oxygen, 40. The combining number of the dry acid is, therefore, 54.

322. COMPOSITION.—The acid obtained by distillation con-

What is said of its absorption by water and the colors produced thereby? What is the composition of nitric acid, and what its combining number? What experiment shows that this acid is formed of nitrogen and oxygen? What is the usual mode of obtaining this acid? In what manner is the strongest nitric acid formed? Whence comes the water to absorb the acid vapor when none is placed in the receiver? What is the specific gravity of the strongest acid? What proportion of water does it contain? How is the dry nitric acid formed? Does the acid obtained by distillation contain the same elements as the dry? What are the constituents of liquid nitric acid?

tains the same elements as the dry acid, and in the same proportions, but with the addition of two proportions of water. Now, the combining proportion of water being 9, that is, oxygen, 8, and hydrogen, 1, it is easy, by the above data, to find the combining or equivalent number for liquid nitric acid. It may be stated thus:

1 eq. of Nitrogen,	14
5 eq. of Oxygen,	40
	54 dry acid.
2 eq. of water, .	18
	72 liquid acid.

The acid in this state is called *hydro* nitric acid, from a Greek word signifying water, to denote its combination with that fluid. When this acid combines with other substances it abandons the water, which, therefore, is not reckoned in its equivalent number. In this state it is called *anhydrous* nitric acid, denoting that it contains no water.

Nitric acid is an exceedingly acrid and corrosive substance. It stains the skin and nails of a permanent yellow, and is an active poison when swallowed.

It parts with its oxygen with great facility, and hence is decomposed by nearly every combustible body. It combines with most of the metals, and decomposes all vegetable and animal substances.

323. Experiments.—As a proof of the slight degree of force with which this acid retains its oxygen, take some warm, dry, and finely-powdered charcoal, and pour on it a few drams of strong nitric acid. The charcoal will be ignited, with the emission of immense volumes of red fumes. By this process the acid is decomposed, and parts with 2 or 3 portions of its oxygen to the charcoal, in consequence of which it is converted into nitrous acid, and deutoxide of nitrogen, which pass off in the form of red fumes.

If an ounce of the spirit of turpentine be placed in a cup, and on it there be poured, suddenly, about half an ounce of this acid,

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What is the chemical name for the liquid nitric acid? When this acid combines with other substances, what becomes of its water? What is the chemical name f the dry acid? What are the properties of nitric acid? How is it shown that t acid holds its oxygen with a slight force? What effect does the action of the char have on this acid? What are the red fumes which pass off during this experime How may spirit of turpentine be inflamed by this acid? Why are the combusti set on fire by this acid?

the turpentine will be inflamed with an explosion, sending forth a great quantity of black smoke, and often throwing the acid and fire to a considerable distance.

In both these cases, the acid parts with its oxygen with so much freedom, and the combustibles absorb it with such avidity, as to set them on fire.

In making the latter experiment, the viol containing the acid should be tied to a long stick, otherwise the operator will be in danger from the explosion.

Nitric acid forms a great number and variety of salts, when combined with the different metals, earths, and alkalies. Most of these salts scintillate when thrown on burning charcoal. This is in consequence of the oxygen which the salt emits, when exposed to heat, and by which the combustion of the charcoal is rendered more vivid. This scintillation is a sure proof that the salt is a nitrate.

All the nitrates are soluble in water, and many of them furnish oxygen gas, of more or less purity, when heated in a retort.

NITROGEN AND HYDROGEN.

AMMONIA.

Equivalent, 17. Symbol, NH_3.

1 eq. Nitrogen, 14+3 eq. Hydrogen, 3.

HARTSHORN.

324. There is a substance well known to artists and others, by the name of *sal-ammoniac.* In chemistry its name is *muriate of ammonia.* If some of this substance be pulverized by itself, and then mixed with an equal portion of unslaked quicklime, also in powder, and then introduced into a retort, upon the application of a gentle heat, there will arise an extremely pungent gas, which is *ammonia.*

Water absorbs this gas with great avidity, and in large quantities, and consequently it can not be collected like most other gases, by means of the water bath.

In the absence of a mercurial bath, therefore, its properties can be examined by receiving it in a bladder attached to the retort, or by means of a tall bell glass, and the apparatus described at Fig. 61. This gas is transparent and colorless. In

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What is said of the salts formed by the combinations of nitric acid? Why do the salts of this acid scintillate when thrown on burning charcoal? What is said of the solubility of the nitrates? How is ammonia obtained? Why can not this gas be collected under water? How may its properties be examined without a mercurial bath? What are the most obvious properties of ammonia?

its pure state it can not be respired. An animal can not live in it, and it extinguishes the flame of burning bodies.

This gas is composed of

1 equivalent, or atom of		nitrogen,	14
3	" "	hydrogen,	3
Its combining weight is, therefore,			17

It is much lighter than atmospheric air, 100 cubic inches weighing only 18 grains.

When this gas is absorbed by water, which will take up more than 500 times its own bulk of it, there is formed the well known pungent liquid called *spirit of sal ammoniac*, or *spirit of hartshorn*, and by the apothecaries, *liquid ammonia.*

When ammoniacal gas is submitted to the pressure of 6 or 7 atmospheres, equal in the whole to about 100 or 120 pounds to the square inch, it is condensed into a clear colorless liquid, but when the pressure is removed, it again expands, and assumes its former gaseous state.

Ammonia is called the volatile alkali, by which it is distinguished from the *fixed* alkalies, soda and potash. It possesses, fully, all the properties of an alkali, having an acrid taste, a strong affinity for water, and being capable of neutralizing the corrosive qualities of the acids.

The article used in smelling bottles, and called *volatile salts*, and *salts of hartshorn*, is a *carbonate* of ammonia.

The salts of ammonia, and particularly the muriate and carbonate, are articles of considerable importance in commerce, in the arts, and in medicine.

325. Preparation of Ammonia.—In a state of purity ammonia is a gas, of which the well known liquor or aqua ammonia is a solution in water. This solution, as above stated, is prepared by mixing intimately sal ammoniac, (hydrochlorate of ammonia,) with an equal weight of slaked lime, introducing the mixture into a glass flask, or retort, which Graham directs, afterward to be filled with slaked lime, and then distilling with the diffused heat of a sand bath. If recourse be had to the flame of a lamp, the heat may conveniently be diffused by placing it within a cylinder of sheet iron, a foot high, as represented at *a*,

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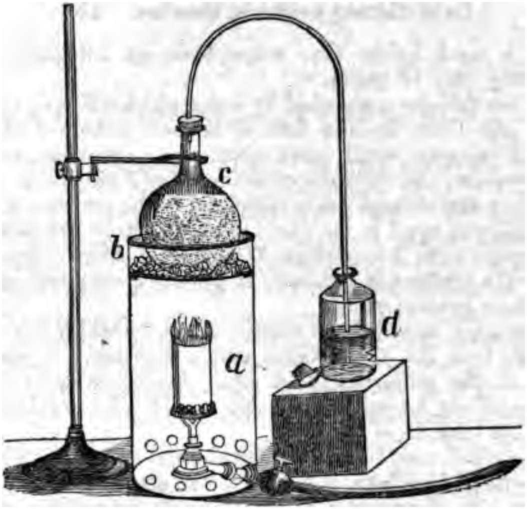
What is the composition of ammonia, and what is its equivalent number? What is the weight of 100 cubic inches of this gas? How is liquid ammonia formed? What quantity of this gas will water absorb? What is said of the condensation of ammonia into a liquid? What is the article called volatile salts? What is said of the alkaline properties of ammonia?

Fig. 88, with a perforated stage, *b*, covered with fragments of brick, or of small pieces of granite, for the diffusion of the heat. On these the flask, *c*, is placed, containing the above named

FIG. 88.



Preparation of Ammonia.

materials. On application of heat, the ammoniacal gas comes over, and is condensed in the bottle *d*, containing water. Chloride of calcium, or muriate of lime, and the excess of lime, will remain in the retort.

CARBON.

Equivalent, 6. Symbol, C.

326. Nature furnishes carbon in its purest state in the form of that precious gem, the *diamond.*

That the diamond is nothing but pure carbon, is proved by direct analysis. If in a glass vessel containing oxygen gas, a piece of diamond be placed, and then exposed to the intense heat

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How is it proved that the diamond is composed of pure carbon? When diamond, or charcoal, is burned in oxygen gas, what is the product?

of a large double convex lens, or burning glass, the diamond entirely disappears, and there remains in the vessel carbonic acid, instead of oxygen. Thus the diamond, like other combustibles, forms carbonic acid by being burned, or by uniting with oxygen. When charcoal, or carbon from wood, is burned in pure oxygen gas, exactly the same result is produced, the charcoal entirely disappears, and the oxygen is converted into carbonic acid.

Charcoal may be obtained for experiments, by burying wood under sand, in a crucible, and exposing it to an intense heat for an hour or two. By this process, the water and other ingredients of which wood is composed are driven off, and the carbon remains.

327. Both diamond and charcoal sustain the most intense degrees of heat, without change, provided oxygen is entirely excluded from them. Charcoal, when newly prepared, possesses the property of absorbing large quantities of air, or other gases, at common temperatures, and of yielding the greater part of them again when heated. There is, however, a great difference in respect to the quantity absorbed, depending on the kind of gas with which the experiment is made. Ammoniacal gas is taken up in the largest quantity, this being 90 times the bulk of the charcoal. Muriatic acid gas is absorbed in the proportion of 85 times the bulk of the charcoal. Other gases are absorbed only in small proportions, nitrogen being only 7½ times, and hydrogen 1.75 times the bulk of the charcoal. The greatest absorption takes place in charcoal made from the most compact kinds of wood, and the amount is much diminished when the charcoal is reduced to powder. Charcoal, recently prepared, has the property of resisting putrefaction in animal substances, and of rendering such substances sweet, after they are tainted. The most offensive stagnant water loses its odor and becomes perfectly sweet by being filtered through powdered charcoal.

It also destroys the color of many substances. Vinegar loses its color, and becomes transparent like water, by being boiled with charcoal; and red wines, or colored brandy, are bleached by passing through it. The best charcoal for these purposes is prepared by calcining animal substances in close vessels.

How may charcoal be obtained from wood in a pure state? What peculiar property does newly prepared charcoal possess? What difference is there in respect to the quantity of the different gases absorbed by charcoal? What gases are absorbed in the greatest, and what in the least quantity? What effect does newly prepared charcoal have on putrifying animal substances? What effect does charcoal have on the color of particular substances? What kind of charcoal is best for the above purposes? Is charcoal a simple, or a compound body?

In the present state of knowledge, charcoal is a simple substance, having resisted all attempts to decompose, or separate it into other elements. Its atomic weight or combining number is 6, this being the proportion in which it is found to unite with oxygen, to form carbonic acid; and in no instance has it been detected in a less proportion in combination.

328. Manufacture of charcoal.—We are curious to know how and where articles of luxury and ornament are manufactured, and yet express no desire to be informed, and indeed remain ignorant all our lives, in what manner many articles of daily use, and of indispensable necessity, are produced. Among the latter articles is charcoal, concerning the manufacture of which very few, except those who do the work, have any, except a general notion, how it is done. Most people know that charcoal is the product of wood, charred or burned in the country, but how this is done, the consumers are generally quite ignorant. Now the production of charcoal, being a process by which the water, pyroligneous, and carbonic acids, hydrogen and other volatile products, are expelled from the wood, may properly be considered as a chemical manufacture, and as such is here described, with appropriate illustrations.

329. In the first place the wood is cut into lengths of four feet, and the logs split, so as to reduce them into pieces of from two to three, or perhaps four inches in diameter, the limbs of about the same thickness remaining round, but well trimmed, so as to pack closely with the split logs. In some cases, shrub wood, as alder and white birch, are employed, the whole mass to be burned consisting of small wood, of only an inch or two in thickness. The wood being prepared, the *coal-pit* is constructed

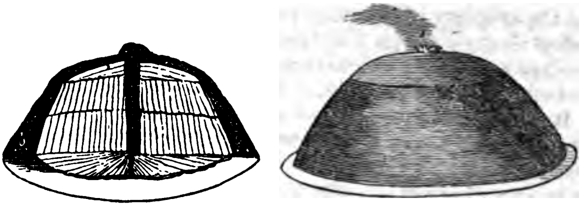
FIG. 89. FIG. 90.

Manufacture of Charcoal.

What is the combining number, or atomic weight, of carbon.

by setting it on end, around a kind of chimney made by laying short pieces across each other, like a quail trap, this forming the center of the whole mass, which is from ten to fifteen feet in diameter, and of a round form, with oblique sides, the whole forming a truncated pyramid. The height is from ten to twelve feet, consisting of two lengths of the wood, set on each other, on the top of which are placed several layers of the same, radiating from the center to the circumference. The mass thus formed is represented by Fig. 89, which shows the form and appearance of the structure, before it is covered. The wood being thus prepared, is next covered with sod, or turf, to the thickness of several inches, small holes being left at the bottom for the admission of the air to the center or chimney, where the fire is kindled. These apertures for the admission of the air are left all around the base, until the fire in the middle is well kindled, when they are stopped with turf. The coal-pit, thus prepared for the fire, is represented by Fig. 90.

330. The fire is kindled at the bottom of the chimney or canal, constructed for this purpose in the center of the pit, as above described. Into this is dropped dry wood and fire, from the top, until by means of the air coming through the apertures left at the bottom for this purpose, the central portion of the mass is well on fire. The chimney, as well as the apertures, are then partially or entirely closed, the quantity of air admitted depending on the state of the fire, or the rapidity of its progress. The burning of a coal-pit requires constant vigilance, and for this purpose it is the common practice to erect in its vicinity a little hut of boards or brush, in which the men sleep and watch by turns, until the burning is finished, which requires from three or four days, to a week or more. During most of this time the attention of one man, at least, is required, in order, by the constant addition of new turf, to prevent the fire from consuming, instead of charring the wood.

It is stated that when the process is well conducted, that dry wood gives about seven-tenths of its weight of charcoal. Generally, says the Prussian chemist, Mitscherlich, we may reckon on 61 to 65 parts of charcoal from 100 parts of wood, or by weight, 24 parts of coal to the 100 parts of wood.

In this country wood is so abundant, that no exact experiments have been made to test the relative proportions between its weight and the charcoal produced, the burners merely calculating that a pile 30 paces around, will produce 1000 bushels of coal.

CARBON AND OXYGEN.

CARBONIC ACID.

Equivalent, 22. Symbol, CO_2.

1 eq. Carbon, 6+2 eq. Oxygen, 16.

FIXED AIR.

331. It has just been stated, that when diamond or charcoal is burned in oxygen, the latter is changed into carbonic acid. By this process the volume of oxygen is not changed, but its weight is increased by exactly the amount of the diamond, or charcoal, consumed. Carbonic acid, therefore, consists of oxygen, with a quantity of charcoal dissolved in, or combined with it.

This acid can, however, be obtained by a much cheaper, and more direct method, than by the combustion of diamond, or even of charcoal, in oxygen gas.

Carbonic acid exists in a fixed state, in vast abundance, as a part of the composition of limestone or marble. This chemical compound, so abundant in nature as to form immense mountains, is composed of 22 parts of carbonic acid, and 28 of lime.

332. PREPARATION OF CARBONIC ACID.—Carbonic acid may, therefore, be obtained most readily, by exposing carbonate of lime to the action of some acid which has a stronger affinity to the lime than the acid has with which it is naturally combined, and thus by forming a new compound between the lime and the stronger acid, the carbonic acid will be set at liberty.

This gas may be developed and purified by the following process. It is so heavy, compared with the atmosphere, that it will displace the air in a bottle, and take its place, running, by decantation, from one vessel to another, like water.

The apparatus, Fig. 91, consists of the glass jar, *a*, into which small pieces of carbonate of lime, or common limestone, are put, and the gas set free by pouring in dilute sulphuric acid, when the carbonic air will pass over into the jar, *b*, containing water, and by which any impurities in the form of vapor will be condensed. The gas will then pass through the U shaped tube, *c*, which contains fragments of chloride of calcium, (muriate of lime,) a compound having a strong attraction for moisture,

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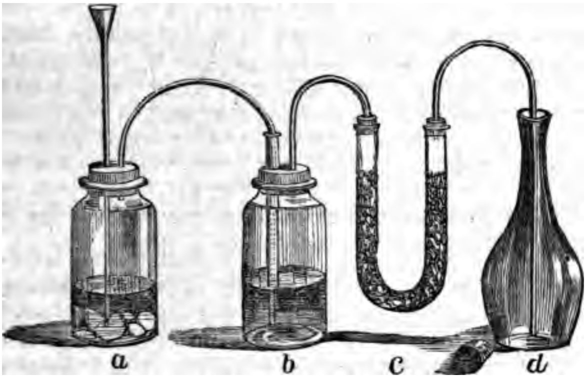
When diamond, or charcoal, is burned in a confined portion of oxygen gas, what effect does the combustion have on the volume and weight of the gas? In what natural compound is carbonic acid contained in great abundance? What proportion of carbonic acid does marble contain? What are the chemical principles on which carbonic acid may be obtained from limestone, or marble?

and which will absorb any aqueous matter the carbonic acid may contain. Lastly, the gas passes into the tall bottle, *d*, in a purified state, where it will remain a considerable time without a cork, in virtue of its great weight.

FIG. 91



Preparation of Carbonic Acid.

333. ACTION.—The chemical changes during this process illustrate the law of simple affinity, formerly explained, viz., that one substance may have an attraction for several others, but with different degrees of force. Thus lime has an affinity for carbonic acid, with which it combines and forms carbonate of lime. But sulphuric acid having a still stronger attraction for the lime, when this is added, the carbonate is decomposed, the sulphuric acid and lime unite and form sulphate of lime, while the carbonic acid being thus rejected, escapes in the form of gas.

334. PROPERTIES OF CARBONIC ACID.—This gas is inodorous, colorless, and elastic. It extinguishes burning substances of all kinds, and is so poisonous that a small quantity of it mixed with atmospheric air destroys animal life.

It is this gas which destroys the lives of many persons every winter, in consequence of warming close rooms with open vessels

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Explain Fig. 91, and describe the process of obtaining carbonic acid gas from marble? Explain how this process illustrates the law of simple affinity. What new salt is formed when sulphuric acid is poured on marble? What is the effect of this gas on flame, and animal life? When charcoal is burned in an open vessel, in a close room, what is the effect on the air of the room? How does pure carbonic acid cause death?

of burning charcoal. In such cases the air becomes noxious from two causes; the charcoal, by abstracting the oxygen from the atmosphere, would leave only the nitrogen, which, as we have already seen, will not support animal life. The mere absence of the oxygen would, therefore, be the negative means of destroying life. But this is not the most active cause of destruction. The air is not only deprived of its oxygen, by the burning charcoal, but the oxygen, by uniting with the charcoal, becomes an absolute poison; this is indeed of so deleterious a nature, that when pure, it causes death by producing a spasm of the glottis, thus closing entirely the passage to the lungs, and when mixed with atmospheric air, in such a proportion as to be taken into the lungs, it then acts as a narcotic poison, producing dimness of sight, loss of strength, difficulty of breathing, then entire suspension of respiration, and finally, insensibility, apoplexy, and death.

335. When limestone is exposed to heat, this gas is driven off, and in consequence of this loss, the limestone is converted into quicklime, a substance well known as the basis of mortar for building. The gas, thus extricated, being quite-pure, is exceedingly deleterious, and sometimes proves fatal to the workmen and others in the vicinity of the kiln, where the burning is performed.

336. FAMILY DESTROYED BY CARBONIC ACID.—M. Foder states, that in the year 1806, a family residing at Marseilles, consisting of seven persons, were all rendered apoplectic, in consequence of breathing carbonic acid, which was extricated from an oven in the yard of the house, where limestone was burning. The gas had come into the house through the door and windows, and by some means it was found, during the night, that the family were in danger, and the alarm was given, but not in time for any one to escape. In the morning all the seven were found in different places, one on the stairs, one on the steps of the door, &c., with lamps in their hands, in the attitude of flight; but the deleterious gas had taken away their strength, and put out their lights. They all appeared to have fallen down of apoplexy, while attempting to escape death by flight. Five were dead beyond recovery, but the two others were brought to life.

When mixed with air, so as to be respired, how does it cause death? When limestone is exposed to a red heat, what changes are produced on it? What were the circumstances under which a family at Marseilles were rendered apoplectic by this gas? Is there any difference between the poisonous effects of charcoal prepared in a coal-pit, and that taken from the hearth?

Some people, who are perfectly aware of the poisonous effects of the air arising from ignited charcoal, which has been prepared in coal-pits, still unaccountably believe, that the coals from a common fire are innocent. This opinion has probably arisen from the circumstance, that coals from the fire are taken up with a quantity of ashes, in which they are chiefly covered, so that their combustion is made less rapid than when charcoal alone is used. But that there is no difference in respect to the poisonous property of this gas, whether the charcoal has been prepared in a coal-pit, or on the hearth, is proved by the fact, that a respectable citizen and his wife, a short time since, had nearly fallen victims to this mistaken opinion.

337. Water absorbs this gas.—Water absorbs carbonic acid from the atmosphere, and it is owing to its presence in spring and well-water, that we are indebted to their pleasant flavor. Boiling causes this gas to escape in consequence of the heat, and whoever has tasted of water immediately from a fountain, and of another portion of the same water, which has been boiled, will observe a remarkable difference. Water which has been recently boiled, will absorb its own bulk of carbonic acid, when agitated with it. The smart and agreeable taste peculiar to soda-water, to lively beer, champaigne, cider, and porter, is owing to the presence of this gas. This shows that, though a deadly poison when taken into the lungs, it may be taken into the stomach, not only with impunity, but with pleasure.

338. The poisonous quality of this gas is a striking instance of the change produced on bodies by chemical combination. Charcoal alone is so inert as to be taken into the stomach in any quantity, without other deleterious effects than what might arise from over distention; and in fine powder it is so far from being injurious to the lungs, that the coalmen consider their business as of the most healthy kind. Oxygen, as it exists in the atmosphere, is the very pabulum of animal life, and when perfectly pure, may be respired without any other ill effects, except what arise from over excitement. But when these two substances are chemically united, they form, as already described, a compound of the most deleterious kind, a poison which, according to M. Hallé, destroys animal life in the space of two minutes.

What is said of the absorption of this gas by water, and the lively taste given the fluid in consequence? Why does water which has been boiled taste flat and insipid? To what liquids does this gas give their smart and lively taste? W[illegible]rove in respect to the poisonous quality of this gas? How do the p[illegible] of this gas illustrate the changes produced on bodies by chemical [illegible]

The specific gravity of this gas is 1.52, air being 1; so that it is about one half heavier than air. It may be poured from one vessel to another, like water; and as it instantly extinguishes flame, lights may be put out with it in a manner which will puzzle and astonish those who are not in the secret. If a short piece of candle be lighted and set in a tumbler, and then a jar of this gas, which in appearance contains nothing, be held so that its contents run into the tumbler, the light will be as effectually extinguished as though the tumbler had been filled with so much water.

339. Test of carbonic acid.—One of the best tests of the presence of this acid is lime water, which, though perfectly transparent before, instantly becomes cloudy or turbid, when the smallest quantity of this gas is blown into it. The small quantity of carbonic acid which is generated in the lungs at every inspiration, is sufficient to form a precipitate in lime water. (*See Respiration.*)

The cause which renders lime water turbid by being mixed with carbonic acid, is easily understood. Water dissolves a small quantity of lime which it holds in solution; but carbonate of lime is insoluble in water. When carbonic acid is blown into a vessel of lime water, the lime instantly combines with it, forming a carbonate of lime, which, being insoluble, is seen in the form of a white cloud. The carbonate thus formed, being heavier than water, sinks to the bottom, or is precipitated.

340. The large quantities of this acid which are formed by combustion and respiration, it might be supposed, would increase the quantity in the atmosphere, particularly in crowded manufacturing cities, so as to make the air poisonous. But as already explained, the wisdom of Omnipotence has prevented the accumulation of this gas in particular places, in consequence of its specific gravity; for experiment shows, that notwithstanding the great difference existing among the gases in this respect, they all mix uniformly. Hence, by this wonderful provision, or exception to the general law of gravity, this gas, though extricated in immense volumes in the free open air, soon diffuses itself on all sides, and mixes with the surrounding atmosphere, so as seldom to prove deleterious by local accumulation.

What is the specific gravity of this gas? How may lights be extinguished by this gas in a manner to puzzle those who are not in the secret? What is a good test for carbonic acid? What effect is apparent when a little of this gas is blown into lime water? Why does lime water become turbid by the presence of carbonic acid? Why is the atmosphere seldom rendered poisonous by the accumulation of this gas?

The composition of this gas has been determined with accuracy, and as seen at the head of this section, it is composed of 2 proportions of oxygen, 16, and 1 proportion of carbon, 6; hence its combining weight is 22.

CARBONIC OXIDE.

Equivalent, 14. Symbol, CO.

1 eq. Carbon, 6 × 1 eq. Oxygen, 8.

341. When two parts of chalk, and one of iron filings, are mixed together and heated in a gun-barrel, *carbonic oxide gas* is obtained.

The student will readily understand the principle of its formation. An *oxide* contains too small a proportion of oxygen to form an acid. When lime or chalk is heated, carbonic acid is extricated, and when iron is heated, it has a strong attraction for oxygen. When, therefore, the chalk and iron filings are heated together, we may suppose, in the first place, that the carbonic acid is extricated, as usual, but that the iron instantly absorbs one half of its oxygen, thus converting the acid gas into an oxide.

This gas possesses the mechanical properties and transparency of carbonic acid. Like that gas, it extinguishes the flame of burning bodies, but is itself inflammable, the light which it puts out, seeting it on fire at the surface, where it burns quickly, with a pale, lambent flame. The combining portion of carbon has been determined from this compound, its elements, carbon and oxygen, having never been found to combine in smaller proportions than 6 of carbon and 8 of oxygen, by weight.

SULPHUR.

Equivalent, 16. Symbol, S.

342. Sulphur is found in the vicinity of volcanoes in large quantities, being *sublimed*, or brought up from the depths below, by the heat of the volcano, where it existed in combination with the metals. It is also found combined with various metals, forming *sulphurets* or *sulphides*, a class of compounds hereafter to be examined; nor is it entirely wanting in the

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What is the composition of this gas, and what its combining number? How is carbonic oxide formed? What are the chemical changes which take place in forming this gas by means of chalk and iron filings? What are the properties of this gas? What is its composition and combining number? In what situation is sulphur chiefly found? Whence comes the sulphur found in the vicinity of volcanoes? How is sulphur described?

animal and vegetable kingdoms, many substances in each containing it in small quantities.

Sulphur is a well known brittle solid, of a greenish yellow color, which has little or no taste, but which emits a peculiar odor when heated, or rubbed.

Its specific gravity is nearly 2, water being 1. When heated to a temperature a little above boiling water, it melts, and becomes completely fluid. In this state it is cast into moulds, and is known in commerce under the name of *roll brimstone.* If the heat is raised to 300 degrees, it loses its fluidity, becomes viscid, and acquires a reddish color. If in this state it be poured into water, it becomes ductile, and is then employed to take the impressions of medals and seals. The color and texture of these false medals have the appearance of some metallic alloy, and those who are unacquainted with their composition, taking them for such, are at first surprised at their lightness.

When sulphur is heated to 500 degrees in a close vessel, it rises in vapor, or *sublimes*, and is condensed unchanged, except in form, which is that of an impalpable powder, well known under the name of *flowers of sulphur.* In this manner it is purified.

Sulphur combines with the earths, alkalies, the metals, and with several proportions of oxygen. Its compounds are therefore numerous, and some of them interesting. It has not been found to combine with any substance in a less proportion than 16, with which it forms an acid, called the hyposulphurous, when united to 8 parts of oxygen.

Sulphur, so far as known, is a simple body; all attempts to decompose it having proved fruitless.

SULPHUR AND OXYGEN.

SULPHUROUS ACID.

Equivalent, 32. Symbol, SO_2.

1 eq. Sulphur, 16+2 eq. Oxygen, 16.

343. When sulphur is burned in pure oxygen gas, the latter suffers no change of volume, but acquires a most suffocating and pungent odor, and many new properties, entirely different

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What is its specific gravity? At what degree of heat does sulphur melt? What is roll brimstone? How is sulphur prepared to take the impressions of medals and seals? How are flowers of sulphur prepared? With what other bodies does sulphur combine? What is the lowest proportion in which sulphur is known to combine? Is it an element, or a compound? How is sulphurous acid gas produced? What effect does this gas produce on flame, animal life, and vegetable colors?

from those of oxygen. The compound so formed is ***sulphurous acid*** gas. It is colorless and transparent; extinguishes flame and animal life; and first turns vegetable blue colors to a red, and then destroys them. When diluted with a large proportion of atmospheric air, it is still so acrid as to produce a sense of suffocation and violent coughing on those who attempt to breathe it.

It is the same gas which is formed when sulphur is burned in the open air, but when burned with oxygen it is pure and undiluted. It possesses the property of bleaching linen, silk, straw, &c., and hence is employed by milliners and others for this purpose.

Its specific gravity is more than double that of atmospheric air, and hence it may be kept for some time in jars by merely covering them with a piece of glass. Its equivalent composition is 16 sulphur and 16 oxygen. Its bleaching property may be shown, by introducing a red rose, or other colored flower, into a jar containing it, which will soon become white. The rose must first be moistened, otherwise the experiment will not succeed. The color may again be restored by an alkali. This gas has a strong disposition to unite with another proportion of oxygen, and hence it will revive some metallic oxides, by depriving them of their oxygen.

This property may be used as the means of making an interesting experiment.

Make a solution of acetate (sugar) of lead in pure water, and with it moisten a piece of ribbon, or a small plant, such as a sprig of mint. The thing moistened of course presents no other appearance than if wet with common water, but when plunged for a moment into a jar of this gas, it comes out completely covered with a coat of brilliant metallic lead.

This chemical change is thus explained. The acetate of lead is an oxide of the metal, dissolved in the acetic acid, or vinegar. The sulphurous acid having a stronger attraction for oxygen than the lead has, the acetate is decomposed by being deprived of its oxygen by the acid, and is thus revived, or brought to its metallic state.

According to Mr. Faraday, the sulphurous acid is condensed

How does this gas differ from that produced by burning sulphur in the air? What is the specific gravity of this gas? What is its equivalent composition? How may the bleaching property of this gas be shown? How may the color of the rose again be restored? How may a ribbon, or small plant, be covered with metallic lead by means of this gas? What are the chemical changes which take place in reviving the lead by this acid? How may this acid be condensed to a liquid state?

and brought into the liquid state, by being submitted to the pressure of two atmospheres, which is equal to that of 30 pounds to the square inch.

This acid unites with metallic oxides, and forms salts, called *sulphites.*

SULPHURIC ACID.

Equivalent, 40. Symbol, SO_3.

1 eq. Sulphur, 16+3 eq. Oxygen, 24.

OIL OF VITRIOL.

344. Sulphuric acid is an article of considerable consequence in commerce and the arts, and is prepared in large quantities in Europe and America.

It was formerly obtained by the distillation of a well known substance called *green vitriol*, or *copperas*, and was therefore called *oil of vitriol.* The composition of this acid, as above seen, gives it the name of *sulphuric acid ;* and green vitriol, therefore, which is composed of this acid and iron, is the *sulphate of iron.*

By distilling this substance at a high heat, it is decomposed, and the acid is obtained in the form of a dense, colorless liquid, of an oily appearance, which emits copious white fumes in the air. If this liquid be again distilled at a lower degree of heat, into a receiver surrounded with ice, there will pass over a colorless vapor, which will condense in the receiver, in the form of a white crystalline solid. This solid is dry, or *anhydrous* sulphuric acid, so called, because it contains no water.

345. The sulphuric acid of commerce is this acid dissolved in water. This acid is prepared by the combination of 8 parts of sulphur mixed with 1 part of nitre, in large chambers lined with sheet lead. The acid is formed in the state of gas, and is absorbed by a thin stratum of water placed on the floor of the chamber. The following is the theory of this process. The sulphurous acid, formed by the burning sulphur, takes a portion of oxygen from the nitre, and is converted into sulphuric acid. This acid then combines with the potash of the nitre, and displaces nitrous and nitric acids in vapor. These vapors are decomposed by the sulphurous acid into nitrous gas, or deutoxide

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What are the salts called which this acid forms with metallic oxides? How was sulphuric acid formerly obtained? What is the chemical name of copperas? How is the dry, or anhydrous sulphuric acid procured? Of what does the liquid sulphuric acid of commerce consist? Describe the manner in which the sulphuric acid of commerce is prepared.

of nitrogen. This gas, suddenly expanded by the heat, rises to the roof of the chamber, where there is an aperture communicating with the open air. There it absorbs a portion of oxygen from the atmosphere, and is converted into nitrous acid vapor, which, being a heavy aëriform body, immediately falls down upon the sulphurous fumes, and imparting a portion of its oxygen to the sulphurous acid vapor, converts it into sulphuric acid, which is then absorbed by the water. The nitrous acid vapor, being thus reconverted into nitrous gas, again ascends to the roof of the chamber for another dose of oxygen, with which it descends as before, and thus the process continues. 100 parts of nitre, and 800 of sulphur, will produce 2000 parts of the acid.

346. From Dr. Ure's paper on this subject, we learn that the common acid of the shops contains from 3 to 4 per cent. of foreign matter, consisting chiefly of sulphate of potash, and sulphate of lead, and that it often contains much more than these proportions, in consequence of the introduction of nitre, to remove the brown color, accidentally given the acid by bits of wood, or straw.

The purest sulphuric acid obtained by the usual process, has a specific gravity of about 1845, water being 1000. If it is much heavier than this, adulteration by means of some ponderous substance may be suspected; and if much lighter, its strength will probably be found deficient in consequence of dilution with water. In consequence of the strong attraction of this acid for water, with which it unites in all proportions, it absorbs moisture from the air with avidity, and thus when vessels containing it are left open, they gain in weight, instead of losing by evaporation. If carboys of this acid are permitted to stand in a damp place, as in a cellar, with the stoppers left out, there will probably be a gain in weight, which will amount to much more than the interest of the money the acid cost. It therefore becomes honest dealers, as well as careful buyers, to see that this acid is well secured from contact with the air.

347. This acid is one of the most caustic and corrosive of all substances. When mixed in the proportion of four parts of acid with one of water, the temperature of the mixture rises to

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What impurities does the sulphuric acid of commerce always contain? What proportion of these substances does the common sulphuric acid of the shops contain? How may the quantity of foreign matter in this acid be ascertained? What is the specific gravity of the best sulphuric acid, obtained by the usual process? What is said of the absorption of water by this acid, when left open? In what proportion does a mixture of this acid and water produce the greatest degree of heat?

300 degrees. Its extreme activity, as a caustic, seems to depend on its avidity for moisture, and the heat occasioned by the union. On the entire skin, when this is dry, it produces no immediate effect, but if there is the smallest erosion, or scratch, it operates on that part instantly, and with the most intense and painful energy. The flesh appears to be first burned, and then dissolved by its action.

In case of any accident, where the concentrated acid is thrown upon the clothes, or skin, as it is generally known that this acid burns, the spectators run for water, which is thrown on, with the intention of diluting the acid, and thus to prevent its further action. This, though meant in kindness to the sufferer, might be the means of his destruction; for the degree of heat, thus raised, would be sufficient to destroy his skin, without the further action of the acid. In such cases, there is much less danger in waiting until some potash, chalk, or even ashes, can be procured, and thrown on the part. Meantime, the sufferer should be stripped of the clothing on which the acid has fallen, and the acid absorbed from the skin with a moistened sponge, or cloth, or even a handful of dry clay, thrown upon the part.

Strong sulphuric acid boils at 620 degrees, and freezes at 15 degrees below zero.

The dry acid is composed of

1 equivalent of sulphur,	16
3 " " oxygen,	24
	40

The common or hydro-sulphuric acid contains, in addition to the above, one proportion of water, making its equivalent number 49.

PHOSPHORUS.

Equivalent, 32. Symbol, P.

348. Phosphorus is a yellowish, inflammable solid, which in the open air emits white fumes, and at common temperatures is luminous in the dark.

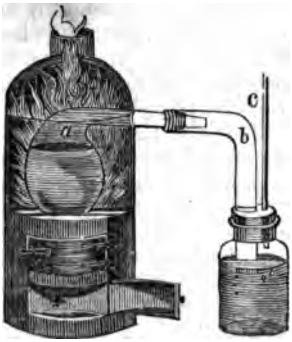
This substance has never been found in a simple state, but

On what does the causticity of this acid seem to depend? In case this acid is accidentally thrown upon a person, what is said to be the best method of neutralizing its effects? What is the composition of the dry acid? What quantity of water does the strongest common acid contain? What is the equivalent number for the hydrosulphuric acid? What is phosphorus? In what state is phosphorus found, in a simple or combined state?

is combined with animal substances, in considerable quantities, and is occasionally found in minerals.

349. HOW OBTAINED.—It is obtained from bones by the following process: In the first place, the bones are calcined, or burned in an open fire, and then pulverized, and digested for two or three days with half their weight of sulphuric acid, to which water is occasionally added. This solution is then mixed with twice its bulk of hot water, and the liquid separated by straining through a cloth. By this process, the bones, which are composed of phosphoric acid and lime, are decomposed, and two new salts, viz., the *sulphate of lime*, and the *biphosphate of lime*, are formed. The sulphate of lime is insoluble in water, and therefore the filtrated solution contains only the biphosphate, which is soluble. Thus, the bones, which are a phosphate of lime, mixed with animal matter, are first deprived of this matter by burning, and then converted, in part, into the biphosphate by the sulphuric acid. We have, then, in this stage of the process, a solution of the biphosphate, or *acidulous* phosphate of lime in water. This solution is then evaporated to the thickness of syrup, mixed with one-fourth of its weight of charcoal in powder, and distilled with a strong heat, in an earthen retort. The charcoal combines with the oxygen of the biphosphate, which, being thus decomposed, the phosphorus distills over, and is obtained in a vessel of water, into which the mouth of the retort is placed.

FIG. 92.



Making of Phosphorus.

The apparatus for this purpose is represented by Fig. 92, and will be understood by mere inspection. The retort *a* is of stone, or clay, so as to bear a considerable degree of heat. The tube *b*, is of copper, and passing air-tight through the cork, dips only a few lines into the water in the bottle. This is a necessary precaution, since, if by any accident, the retort should be suddenly cooled, only a small quantity of water, and not enough to reach the hot retort, could be absorbed, other-

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By what process is phosphorus obtained? Describe the different chemical changes which takes place in the process of its preparation.

wise, sad accidents might occur, since only a few drops of water, converted into steam, would burst the retort, and throw its contents in all directions. The small tube *c*, open at both ends, is for the purpose of allowing the gasses, which come over during the process to escape. The heat, in the furnace, is to be gradually increased, when the phosphorus, which comes over in a liquid form, will be condensed in the water, and in the neck of the retort. Large quantities of this article are manufactured and employed in making friction matches, and for other purposes. It is a brilliant experiment, since, during the process, sulphureted hydrogen escapes, which takes fire as it reaches the air. It also requires much care and experience, otherwise it is not without danger.

350. PROPERTIES.—Phosphorus, thus obtained, is of a yellowish, or flesh color, but may be made colorless and transparent by redistillation.

This substance is exceedingly inflammable, so that at common temperatures, it is necessary to preserve it under water, in well stopped bottles. It may be set on fire by slight friction, or even by the heat of the hand. It is insoluble in water, but is soluble in ether, or oils, to which it communicates the property of shining in the dark.

Put a piece of phosphorus into a vial half filled with olive oil, then keeping the thumb on the mouth of the vial, warm the bottom, shaking it now and then, until the phosphorus is melted. This forms *liquid phosphorus*, and a vial thus prepared may be occasionally useful to show the hour of the night by a watch. All that is necessary for this purpose is to hold the vial in the hand for a few minutes, until it becomes warm, then take out the cork, and the union of the oxygen of the air with the phosphorus will evolve sufficient light to see the hour.

That the light is owing to the combination of oxygen with the phosphorus, or to its slow combustion, in the above instance, is proved by the fact, that phosphorus may be melted and sublimed in pure nitrogen, without the least appearance of light. Its combustion in oxygen gas is exceedingly vivid, and affords a striking and splendid experiment for a public lecture room.

When taken into the stomach, phosphorus proves a virulent and deadly poison; though in minute doses, it has been used as a medicine, when dissolved in ether.

What is said of the inflammability of phosphorus? In what manner must it be preserved from the air? How is liquid phosphorus prepared? For what purpose may a vial of this mixture be useful? How is it proved that the luminous appearance of phosphorus is owing to the absorption of oxygen? What is said of the poisonous quality of this gas when taken into the stomach?

PHOSPHORUS AND OXYGEN.

PHOSPHORIC ACID.

Equivalent, 72. Symbol, PO_5.

1 eq. Phosphorus, 32+5 eq. Oxygen, 40.

351. Phosphorus, as above stated, unites with oxygen with great rapidity, and affords an instance of intense chemical action, attended with the most brilliant phenomena. During this combustion, copious white vapors are produced, which fall to the bottom of the vessel in which the experiment is made, like flakes of snow. This white vapor is the dry, or anhydrous phosphoric acid. If exposed to the air, it soon attracts moisture in sufficient quantity to dissolve it, and thus becomes liquid phosphoric acid.

This acid may also be formed by the action of nitric acid on phosphorus. The union is made by dropping pieces of phosphorus into the strong acid. The phosphorus absorbs one proportion of oxygen from the acid, thus converting this acid into the deutoxide of nitrogen, or nitrous gas, which escapes in immense volumes during the process. The phosphorus is thus converted into phosphoric acid, which is obtained in the solid form by evaporating the solution to dryness.

Phosphoric acid unites with water in all proportions, and produces a small degree of heat during the solution. Its taste is intensely sour, but it is not corrosive. When heated in contact with charcoal, the latter absorbs its oxygen, and the phosphoric acid is converted into phosphorus. This acid combines with various bases, and forms a class of compounds called *phosphates*. Its composition is

1 proportion of phosphorus,	16
2 " " oxygen,	16
Consequently its equivalent is	32

PHOSPHORUS ACID.

Equivalent, 56. Symbol, PO_3.

1 eq. Phosphorus, 32+3 eq. Oxygen, 24.

352. This acid is obtained by exposing pieces of phosphorus to the open air, in consequence of which it spontaneously absorbs oxygen, and undergoes a slow combustion.

What is said of the union of phosphorus and oxygen? In what form does the dry phosphoric acid appear? Why does this acid become liquid on exposure to the air?

If two or three sticks of phosphorus be thus exposed in a glass funnel, set into the mouth of an empty bottle, the acid will be formed, and by attracting moisture from the air, will be dissolved, and pass down into the bottle, where at first may be found a quantity of liquid phosphorous acid. This acid combines with different bases, and forms salts, which are called *phosphites.* Phosphorus acid, when exposed for some time to the air, absorbs another proportion of oxygen, and is then converted into phosphoric acid. Indeed, the acid formed by this method is probably always mixed with the phosphoric acid.

There are several other compounds of phosphorus and oxygen, but these are the most important. The phosphates will be described in their proper place.

BORON.

Equivalent, 11. Symbol, B.

356. There is a solid substance, resembling alum in appearance, which is used in medicine and the arts, under the name of *borax.* From borax there is extracted an acid, called the *boracic* acid. When boracic acid is heated in contact with the metal called *potassium,* the metal, having a strong affinity for oxygen, deprives the acid of that principle, and thus its base, called *boron,* is set free. This, so far as is known, is an element. Boron is insoluble in water, alcohol, or oil. It may be exposed to the strongest heat in a close vessel, without change, but when heated to about 600 degrees in the open air, it takes fire, burns vividly, and by the absorption of oxygen, is again converted into boracic acid.

353. Boracic acid.—This is the only known compound of boron and oxygen. It is a natural product, occasionally found in springs, and also in several salts, of which borax, or the *borate of soda,* is the principal.

The acid may be obtained from the borate of soda, by dissolving that substance in hot water, and then adding sulphuric acid until the solution becomes sour. Sulphuric acid combines with the soda, forming sulphate of soda, or Glauber's salt, while the boracic acid thus set free, is formed, when the water cools,

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By what other method may this acid be formed? When phosphorus is thrown into nitric acid, what are the chemical changes which ensue? In what manner does charcoal convert phosphoric acid into phosphorus? What is the composition, and what the combining number of this acid? How is phosphorous acid obtained? What are the salts called which this acid forms with the different bases? How is boron obtained? Is boron a compound, or an elementary body? What are the properties of boron? What is boracic acid? How may boracic acid be obtained? What is the common name for borate of soda?

in small crystals. It is not readily soluble in water, but alcohol dissolves it freely, which being set on fire, burns with a beautiful green flame. This green flame is a good test of the presence of boracic acid in any composition.

This acid is composed of

Boron,	1	equivalent,	11
Oxygen,	6	"	48
The combining pro. of this acid is therefore			59

CHLORINE.

Equivalent, 36. Symbol, Cl.

OXMURIATIC ACID.

355. This highly important and useful gas is obtained by the action of muriatic acid on black, or peroxide of manganese. The most convenient mode of preparing it is by mixing strong muriatic acid, contained in a retort, with half its weight of the black oxide of manganese in fine powder, and then applying a gentle heat. The gas may be received in glass bottles filled with water, and inverted in the pneumatic cistern, in the usual way. The water should be warmed, to prevent absorption.

356. **Mr. Fownes' method.**—The following are Mr. Fownes' directions for the preparation of chlorine. Fig. 93, a large glass flask, *a*, containing a quantity of common salt, is fitted with a cork and safety tube, *b*, with a bent tube, *c*, the latter passing through a short tube into a wide necked bottle, containing a little water, into which the open tube dips. A second bent tube, *d*, passes by another hole in the cork, into the bottle, *e*, but only just through the cork. This tube passes into another bottle containing distilled water. The tubes are of glass, and the joints through the cork made tight by bees-wax.

Action.—Having thus prepared the apparatus, pour through the funnel, *b*, sulphuric acid, about equal in weight to the salt, when the gas will be developed, which at first will be absorbed by the water in the bottle *e*, but when this is saturated, it will pass in the other bottle by the tube, *d*, in a pure state. When the action ceases, an additional quantity of gas may be obtained by the application of heat, by means of charcoal placed in the furnace under the flask. As much heat is given out by the

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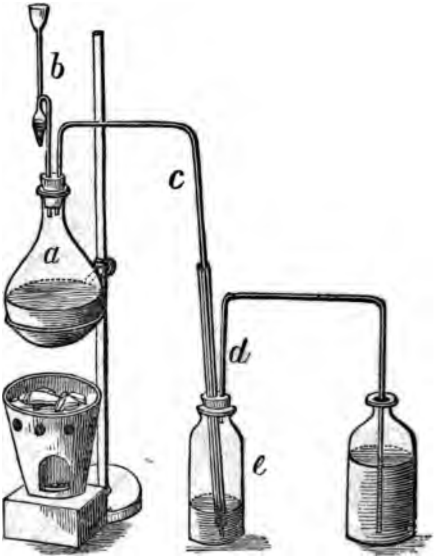
What is the best test for the presence of boracic acid? What are the elements of boracic acid, and what is its combining number? How is chlorine obtained? What are the two processes, described, of obtaining it? What is said of the color and suffocating effects of this gas?

condensation of the gas, the condensing bottle may be surrounded with cold water, being placed in a vessel for this purpose.

357. Observation.—It will be observed that this method differs materially from that first described, in which the articles employed are muriatic acid and oxide of manganese. The result, however, is exactly the same, the chlorine being in the first case the product of the mutual action of the manganese and muriatic acid, and in the second, by the action of the sulphuric acid on the muriate of soda, or common salt.

FIG. 93.



Manufacture of Chlorine.

358. Properties.—This gas is of a yellowish green color, the name, chlorine, in Greek, signifying green. It has an astringent taste, and is so exceedingly suffocating, that a bubble or two let loose in a room, will excite coughing and a sense of strangulation. Cold water, recently boiled, will absorb twice its volume of chlorine, which it gives out again on being heated.

The specific gravity of this gas is 2.5, so that it is more than twice as heavy as atmospheric air. 100 cubic inches weigh 76.25 grains, while the same quantity of common air weighs only 30.5 grains.

Chlorine, in solution with water, was formerly called *oxymuriatic acid*, from the opinion that it was composed of muriatic acid and oxygen. But, according to the logic of chemistry, it is now universally considered a simple body, having never been decomposed, though repeatedly submitted to the most active decomposing agents known to chemists. Sir H. Davy submitted it to the most powerful effects of galvanism, and to charcoal heated to whiteness, without decomposition, and without separating the least trace of oxygen from it. Hence, according to the present state of knowledge, it is an elementary body.

Chlorine is a supporter of combustion. When a lighted taper is plunged into this gas, it burns with a small red flame, emitting a large quantity of smoke. Phosphorus takes fire in it spontaneously, and so do several of the metals.

Fill a deep bottle, or large tube, with this gas, and set it upright, with the mouth covered by a plate of glass. Have some antimony prepared, by being pounded in a mortar; then slide off the cover and pour in the metal. It will take fire before it reaches the bottom, and afford a beautiful shower of white flame. This affords an elegant and striking experiment. The metals, tin, zinc, copper, arsenic, and even gold, when in the state of powder, or thin leaves, will be inflamed in the same manner.

Chlorine has a very strong attraction for hydrogen, but it is through the mysterious influence of light that the combination between the two substances seems spontaneously to be effected.

Thus, when a mixture of these two gases is kept in the dark, no combination ensues, but if exposed to the direct light of the sun, they combine suddenly, and with a violent detonation. This sometimes happens without the sun's light.

This gas, though formerly called an acid, does not appear to possess any acid properties. It is not sour to the taste, nor

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What is its specific gravity? What was the former name of this gas? Does this gas contain any oxygen? What is said of the experiments of Sir H. Davy on chlorine? Is this an elementary, or a compound body? Is chlorine a supporter of combustion? What substances take fire in this gas spontaneously? In what manner may a shower of flame be made by this gas and a metal? What is said of the union between this gas and hydrogen? Does chlorine contain any of the properties of an acid?

does it redden vegetable blue colors, properties nearly universal in the acids.

But the most important property of chlorine, is its bleaching power, all vegetable and animal colors being discharged by its action. For this purpose, it is combined with quicklime, forming *chloride* of lime, or *bleaching powder*, an article very extensively employed at the present time, and which will be described, and its properties examined, in its proper place.

Another very important property of chlorine is its disinfecting power, any infectious or disagreeable odor being almost instantly destroyed by it. For this purpose, the chloride of lime is also chiefly employed. The compounds of chlorine which are not acid, are called *chlorides*, or *chlorurets*. When chlorine, united to oxygen, combines with a base, and forms a salt, it is called a *chlorate*. These were formerly called *hyperoxymuriates*. They possess no bleaching properties.

CHLORINE AND HYDROGEN.

HYDROCHLORIC ACID.

Equivalent, 37. Symbol, Cl. H.

1 eq. Chlorine, 36+1 eq. Hydrogen 1.

MURIATIC ACID.

359. We have just seen that chlorine has a strong affinity for hydrogen, but that no union takes place between them, without the influence of light. When the light is entirely excluded, a mixture of these gases remains without change. When the mixture is made in a glass vessel, and exposed to the light of day in the shade, the gases, if of equal volumes, slowly combine, and form muriatic acid gas. But when the mixture is exposed to the direct rays of the sun, the union is sudden, and attended by an explosion.

This combination does not change the volume of the original mixture, but the properties of the two gases are greatly changed. If the vessel in which the experiment has been made is unstopped under water, the fluid will in a few moments entirely absorb its contents, and fill the vessel in its place, while the two

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What is the most important property of chlorine? What does chlorine form, when combined with quicklime? What other important and useful property has this gas? What are the compounds of chlorine, which are not acid, called? When a mixture of hydrogen and chlorine is kept in the dark, what change takes place? When placed in the shade, what is the effect? When the mixture is placed in the sun, what effect is produced? What are the changes produced on these gases by this combination? What is the name of the new gas?

gases, before combination, were absorbed by water only in small proportions. The peculiar odor of chlorine, and its prompt bleaching property, are also destroyed, and other change of properties will become apparent on further examination.

The compound formed by the union of chlorine and hydrogen is called *hydrochloric acid.* This gas is composed by weight of

1 equivalent of chlorine,	36
1 " " hydrogen,	1
Combining weight of hydrochloric acid gas,	37

360. The production of muriatic acid by the combination of its elements, is designed to prove its constitution, and combining proportions. This acid is, however, much more readily prepared by the action of sulphuric acid on common salt.

If the salt be pulverized and mixed with an equal weight of the acid, and then the heat of a lamp applied, muriatic acid gas will be disengaged. But it must not be received over water, which will absorb several hundred times its own bulk of this gas.

Muriatic acid gas is a transparent, elastic fluid, of a very pungent smell, and intensely acid taste. Its attraction for water is so great, that when it escapes in the open air, even in the dryest season, it instantly forms a white cloud, in consequence of combining with the moisture of the atmosphere.

Water, at the temperature of 40 degrees, absorbs 480 times its bulk of this gas, and the solution is known under the name of *muriatic acid*, or *spirit of sea salt*, and is largely employed for chemical and manufacturing purposes.

This acid is prepared, in the large way, by extricating the gas from sea salt, by sulphuric acid, as above described, and then passing a current of it into water, as long as any is absorbed. It forms, with the different bases, a class of salts, called *muriates*, or *hydrochlorates.*

When this gas, in a pure state, is submitted to the pressure of 40 atmospheres, that is, 600 pounds to the square inch, it is condensed into a liquid.

What is said of the absorption by water of chlorine, and hydrogen, and also of muriatic acid gas? What is the composition of muriatic acid gas, and what is its combining number? How is this gas most readily and conveniently prepared? Why does muriatic acid gas form a white cloud in the open air? How man its own bulk of this gas will water absorb? Under what name is this solutio in water known? How is the muriatic acid of commerce prepared?

CHLORINE AND OXYGEN.

361. There are four compounds of chlorine and oxygen, formed by the union of as many different proportions of the oxygen to the same proportion of chlorine. These compounds are known only to chemists, and with the exception, perhaps, of chloric acid, possess no value in the arts. They are all formed by the action of an acid on the chlorate of potash, or the chlorate of barytes. The chief interest which these substances possess, in a chemical relation, is their strict conformity to the laws of definite and multiple proportions. Their names and constituents are as follows:

Protoxide of chlorine,	36	chlorine	+ 8	oxygen.
Peroxide of chlorine,	36	"	+32	"
Chloric acid, . .	36	"	+40	"
Perchloric acid, .	36	"	+56	"

Thus, the first is composed of 1 proportion of chlorine combined to 1 of oxygen. The second, 1 of chlorine and 4 of oxygen. The third, 1 of chlorine and 5 of oxygen. The fourth, 1 of chlorine and 7 of oxygen.

The equivalent numbers, therefore, for the first, is $36+8=44$; the second, $36+32=68$; for the third, $36+40=76$; and for the fourth, $36+56=92$.

CHLORINE AND SULPHUR.

CHLORIDE OF SULPHUR.

Equivalent, 52. Symbol, S. Cl.

1 eq. Sulphur, 16+1 eq. Chlorine, 36.

The combination of chlorine with sulphur forms a curious compound, called *chloride*, or *chloruret of sulphur.* The method of forming this combination is as follows:

362. PREPARATION.—The materials for making chlorine, it will be remembered, are black oxide of manganese, and muriatic acid. These being placed in the flask, *a*, Fig. 94, and the heat of a lamp applied, the chlorine will rise, and pass down the tube into the globe, *b*, where any water it contains is condensed. Rising from *b*, the gas passes through the tube, *c*, containing

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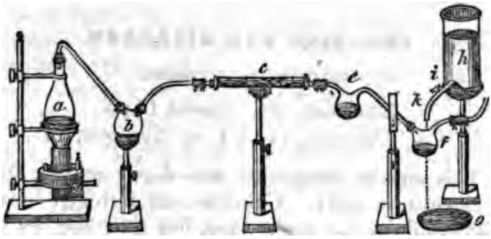
Under what pressure is this gas condensed into a liquid? How many compounds of chlorine and oxygen are known? Do the compounds of chlorine and oxygen possess any value in the arts? In what relation are the compounds of chlorine and oxygen interesting?

chloride of calcium, by the absorption of which it will be deprived of all moisture, so that it will arrive at *e*, which contains the sulphur, in a perfectly dry state. The globe, *e*, must be gently heated by means of a spirit lamp, so as to melt the sulphur.

FIG. 94.



Preparation of Chloride of Sulphur.

By these means, the sulphur and chlorine are made to combine and pass in the gaseous state into the globe, *f*, which being kept cold by means of a stream of water from the cistern, *h*, the compound is condensed into the liquid form. The quantity of water is regulated by means of the stop-cock, *i*, affixed to the tube, *k*, and falls from the globe into the dish, *o*. The superfluous gas passes off into the open air, by the waste pipe, *l*. By this method small quantities of the chloruret of sulphur may be formed.

363. Properties.—Chloruret of sulphur is a yellowish red fluid, of a peculiar and disagreeable odor, whose boiling point is 346 degrees. It sinks in water, by which, in a short time, it is decomposed, and resolved into hydrochloric and sulphuric acids, and sulphur. The chlorine combines with the hydrogen of the water, while the oxygen of the water combines with one fourth part of the sulphur thus set free to form sulphuric acid. The remaining three parts of the sulphur are separated in the solid form.

Chloruret of sulphur is composed of 100 parts of sulphur, and 110 parts of chlorine, by weight.

By allowing chlorine to pass over this compound for a time,

What is the atomic weight, or chemical equivalent of chlorine? What are the names, and what the combining numbers, of the four compounds of chlorine and oxygen?

another portion is absorbed, and a new compound is formed, which contains twice as much chlorine as the chloruret; this is a chloride of sulphur, and is of a dull red color.

The chloruret dissolves sulphur, and is capable of taking up much more when heated than when cold. Hence, if the heated solution be saturated, and then cooled, beautiful crystals of sulphur are deposited.

CHLORINE AND NITROGEN.

CHLORIDE OF NITROGEN.

Equivalent, 158. Symbol, Cl_4N.

4 eq. Chlorine, 144+1 eq. Nitrogen, 14.

364. This curious compound was discovered by Dulong, a French chemist, in 1811. Chlorine and nitrogen have but a very slight affinity for each other, but they may be made to combine, by passing a current of the first through a solution of nitrate of ammonia. (Nitric acid, it may be remembered, consists of the two elements, oxygen and nitrogen, and ammonia is composed of hydrogen and nitrogen. By the union of these two compounds, nitrate of ammonia is formed.) To prepare chloride of nitrogen, dissolve an ounce or two of the nitrate of ammonia, in 14 or 16 ounces of hot water, and when the solution has cooled to about 90 degrees, invert in the solution a glass jar, with a wide mouth, filled with chlorine. The solution gradually absorbs the chlorine, and consequently, rises in the jar, at the same time acquiring a yellow color. In about half an hour, minute globules, of a yellow fluid, like oil, are seen floating on its surface. These, by uniting, acquire the size of small peas, when they sink to the bottom of the vessel. These globules are the chloride of nitrogen. They are formed by the decomposition of the ammonia in the solution; the chlorine combining with its nitrogen, and thus forming the compound in question. A cup of lead, or glass, should be placed at the bottom of the solution, and under the mouth of the jar, to receive the product.

365. PROPERTIES.—The chloride of nitrogen is the most violently explosive substance yet discovered, and should not be experimented upon by the student in quantities larger than a mus-

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What is said of the affinity between chlorine and nitrogen? What is the composition of nitrate of ammonia? How is the chloride of nitrogen prepared? What chemical changes take place in the formation of chloride of nitrogen? What cautions are given with respect to experimenting on this compound?

tard seed at a time, and even in this quantity, with great caution. Both its discoverer, and Sir H. Davy, notwithstanding their experience and caution, as chemical experimenters, were seriously injured by its violence. At the temperature of about 200 degrees it explodes, and at common temperatures, when thrown on some combustibles. When a small globule is thrown into olive oil, or spirit of turpentine, it explodes with such violence as to shatter any vessel of glass in pieces.

The violence of its detonation is owing to the great volume of the products which are formed at the instant. The compound consists wholly of the two gases, chlorine and nitrogen, condensed, and combined with each other. When, therefore, the explosion takes place, these two elements assume their gaseous forms, thus, in an instant, occupying a vast space, when compared to their former state.

Chloride of nitrogen consists of

1 equivalent of nitrogen,	14
4 " " chlorine,	144
Making its number,	158

IODINE.

Equivalent, 126. Symbol, I.

366. The next simple substance we shall examine, is *iodine*. Its name signifies in Greek, "violet colored," because, when in the state of vapor, it is of a most beautiful violet color.

Iodine was discovered at Paris by a manufacturer of nitre, in 1812. This substance is obtained from the lye made of the ashes of marine vegetables, or from the substance called *kelp*, or *barilla*, which is an impure alkali, made during the manufacture of soda.

367. PREPARATION.—Dissolve the soluble part of kelp, or the ashes of sea-weeds in water; concentrate the solution by evaporation, when crystals of carbonate of soda will appear, which must be separated. Then pour the remaining liquor into a clean vessel, and mix with it an excess of sulphuric acid. Boil this liquid for some time, and then strain it through a cloth. Put this liquid into a small flask, and mix with it as

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At what temperature does this compound explode? What combustible substances cause it to explode at common temperatures? Explain the cause of its violent explosion. What are the combining numbers for its constituents, and also for the compound? What does the name iodine signify, and from what circumstances has it derived its name? By what process is iodine prepared?

much black oxide of manganese, by weight, as there was sulphuric acid; then attach to the mouth of the flask a glass tube, closed at the upper end, and apply the heat of a lamp to the flask. The iodine will be sublimed, and will attach itself to the tube in small brilliant scales resembling black lead.

Iodine thus obtained is a friable solid, with a brilliant metallic luster, and bluish gray color. Its taste is hot and acrid, and it is sparingly soluble in water. It corrodes the cork of the vial in which it is kept, and escapes—is a strong poison when taken in large doses; but in solution with alcohol, which dissolves it freely, has been considerably used as a medicine.

When heated in a retort to about 250 degrees, it evaporates, and fills the vessel with an exceedingly rich violet colored gas. As the retort cools, it again condenses in fine brilliant points resembling frost on the glass. If exposed to the open air, it slowly evaporates, and if handled, it leaves a brown stain on the fingers.

Iodine resembles chlorine in smell, and in some of its properties, particularly in destroying vegetable colors. Like oxygen and chlorine, it is a non-conductor of electricity, and is a negative electric. So far as is known, it is a simple body. It has a strong attraction for the pure metals, and the simple non-metallic substances, such as sulphur and phosphorus. These compounds are called *iodides.*

The best test for iodine, in its free state, is starch, with which it forms an insoluble compound in water, of a deep blue color. This test is so delicate as to indicate the most minute portion of starch in solution.

Iodine combines with hydrogen, oxygen, and chlorine, forming *hydriodic acid*, *iodic acid*, and *chloriodic acid.* Among these, the hydriodic acid, only, is of any importance or use.

IODINE AND HYDROGEN.

HYDRIODIC ACID.

Equivalent, 127. Symbol, HI.

1 eq. Iodine, 126 + 1 eq. Hydrogen, 1.

368. When iodine is heated in a porcelain tube with hydrogen gas, the two substances combine and form a compound in

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What is the appearance of iodine? What are its sensible properties? What are its uses? What is the effect when it is heated in a retort? When exposed to the open air, what is the consequence? In what respects does iodine resemble chlorine? What is its electrical state? Is iodine a simple, or a compound body? For what substance has iodine a strong attraction? What is the atomic weight of iodine?

the form of a gas, which has acid properties, and which is rapidly absorbed by water. This is the hydriodic acid.

This gas is without color, is very sour to the taste, reddens the blue colors of vegetables, and has an odor similar to muriatic acid gas.

It combines with alkalies, forming salts, called *hydriodates.*

The discovery of iodine was one of the means of subverting the former doctrine, that oxygen was the universal acidifying principle, the above instance showing that compounds, having all the properties of acids, are formed by the combination of hydrogen with iodine. Several other instances of similar nature have been discovered, as in the case of muriatic acid. These instances appear, however, to be only exceptions to a universal principle, oxygen being still the acknowledged agent by which most acids are formed.

369. HYDRIODATE OF POTASH.—This is given a place here, instead of among the salts, because it is the only salt of the kind to be described, and because, in manufacturing this compound, the method of obtaining the hydriodic acid is different from that stated above. It is the only hydriodate of any use or importance, and does not exist as a salt in a separate state, but only in solution.

In preparing hydriodate of potash for medicinal use, the preliminary labor of forming the acid may be dispensed with, and the salt in solution may be formed by a very simple process, as follows:

Add to a hot solution of pure caustic potash in water, as much iodine as it is capable of dissolving. This will form a solution of a reddish brown color, consisting of the iodate and hydriodate of potash, together with an excess of free iodine.

Through this solution, a current of *sulphureted hydrogen gas* is transmitted, until the free iodine and iodic acid are converted into hydriodic acid, changes which may be known to be accomplished by the appearance of the liquid, which will gradually lose its brown color, and become colorless and transparent. The solution is then heated to expel the remaining sulphureted hydrogen, and after being filtered, is pure hydrio-

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What is the most delicate test for iodine? How may hydriodic acid be formed? What are its sensible properties? What are the salts called which this acid forms with alkalies? How does this acid demonstrate that oxygen is not the universal acidifying principle? Are there any other instances in which an acid is formed without oxygen? What is said relative to these exceptions to a general principle? How is the hydriodate of potash formed? What does the reddish brown solution consist of? How is it known when a sufficient quantity of sulphureted hydrogen has been passed through the solution of iodine?

date of potash, in aqueous solution. This solution is considerably employed, as a medicine, in scrofula, and other glandular diseases.

BROMINE.

Equivalent, 78. Symbol, Br.

370. The name *bromine* is from the Greek, and signifies a "strong, or rank odor."

Bromine, after undergoing various and multiplied tortures, by means of the most powerful decomposing agents, is arranged as an elementary body, having endured fire, galvanism, &c., without loss of integrity.

It was discovered by Balard, of Montpelier, in 1826, and like iodine, exists in the ashes of marine vegetables, and also in sea water. In the water of the Dead Sea it is found in large quantities.

The process of extricating it is too intricate to be detailed in this work, nor would it ever be undertaken by pupils in chemistry, for which this book is designed.

Bromine is a fluid of a hyacinth red color, when viewed by transmitted light; but of a blackish red, when seen in the ordinary manner, or by reflected light. Its odor resembles that of chlorine, but is much more disagreeable. Like iodine, it corrodes wood or cork, and stains the fingers of a yellowish hue. Its specific gravity is 3. It is a strong poison. It is volatile at common temperatures, and emits red vapors similar to those of nitrous acid.

A lighted taper is soon extinguished by it, but before going out it burns with a flame which is green at the base and red at the top.

Bromine does not turn blue vegetable colors red, but like chlorine, destroys them.

From these properties it will be observed, that this substance has many characters in common with iodine and chlorine.

Bromine combines with oxygen, hydrogen, and chlorine, but these compounds are little known, and of no interest except to professed chemists.

What is the use of the hydriodate of potash? **What does the name bromine signify? Is it an element, or a compound?** In what **substance does it exist? What is** the appearance of bromine? In what respects is it similar to iodine? **In what respect** does it resemble chlorine in properties? What **is** the **equivalent number of** bromine?

FLUORINE.

Equivalent, 19. Symbol, F.

371. It is a singular circumstance in chemistry, that the base of the fluoric acid has never been detached from the acid itself, notwithstanding every effort has been made on the part of the chemists to effect a separation. It will be remembered, that all the other acids consist of a base united to an acidifying principle, and that the two elements have been examined in separate states. Thus, sulphuric acid consists of sulphur and oxygen; carbonic acid, of carbon and oxygen, &c.

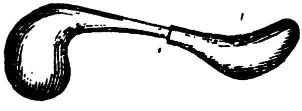
The base of this acid, however, has been named *fluorine;* but whether this is united to oxygen, as the acidifying principle, or whether such a base exists or not, is unknown. Fluoric acid must, therefore, at present, be examined as a simple body, or in connection with substances to which it unites.

This acid exists in nature in considerable quantities, being found combined with lime, forming the salt called *fluate of lime*, but more commonly known under the name of *Derbyshire spar.* This latter substance is found crystallized, and of various colors intermixed, forming, when polished, one of the most beautiful productions of the mineral kingdom. It is in common use, for vases, candlesticks, snuff-boxes, &c.

372. PROCESS FOR FLUORIC ACID.—To obtain fluoric acid, a quantity of fluate of lime is powdered, and submitted to the action of twice its weight of strong sulphuric acid, in a retort of lead. On the application of a gentle heat to the retort, the acid distills over, and must be received in a leaden vessel.

The retort and receiver, Fig. 95, made of sheet lead, and soldered together on the edges, and the juncture between them stopped with a lute of clay, will answer very well. The white fluor must be selected for this purpose, as being most pure. It is first put into the retort, the acid poured in, and then connected with the receiver, which must be surrounded with a mixture of common salt and snow, or powdered ice, to keep it cold.

FIG. 95.



Process for Fluoric Acid.

Has the base of fluoric acid never been detached from the acid itself? Is the same true of any of the other acids? What is the base of fluoric acid called? Is it known that any such base exists? What natural substance contains fluoric acid? How is fluoric acid obtained from fluate of lime?

Fluoric acid, at the temperature of 32 degrees, or the freezing point, is a colorless liquid, and will retain its liquid state, if preserved in well stopped vessels, when the temperature is 60 degrees. But if exposed to the air when the temperature is above 32 degrees, it flies off in dense white fumes, which consist of the acid, and the moisture of the air with which it combines.

No substance with which we are acquainted has so strong an affinity for water as fluoric acid. Its liquid state appears to be owing to the water which is distilled over from the sulphuric acid during the process of obtaining it, and no process yet devised has succeeded in freeing it entirely from moisture. When a single drop is let fall into water, a hissing noise is produced, like that occasioned by the plunging of a red hot iron into the same fluid, such is the heat produced by its combination with water.

In experimenting with this fluid, the utmost caution is necessary; for no substance so instantly and effectually disorganizes the flesh, and produces such deep and obstinate ulcers, as this. The least particle would inevitably destroy an eye, or create an obstinate ulcer on any other part.

373. PROCESS OF ETCHING ON GLASS.—Fluoric acid has the singular property of corroding glass, and may be used for this purpose in the fluid state, as above described, or in the gaseous form, the latter of which is commonly the most convenient.

Any design may be etched on glass, by the following simple method:

First, cover the glass with a coat of bees-wax, or engravers' varnish. If wax is used, it must be spread over the surface as thin as possible. This is done by heating the glass over a lamp, and at the same time rubbing it with wax. A thin and even coat may thus be obtained.

Next draw the design by cutting the wax with a sharp pointed instrument, quite down to the glass, so that every line may leave its surface naked; otherwise the design will be spoiled, since the acid will not act through the thinnest film of the wax. A large needle answers for a graver for this purpose.

Having made the design, the etching is done by placing

What is the appearance of fluoric acid at the temperature of 32 degrees? What is its appearance when exposed to the open air, at a temperature above 32 degrees? What is said of the affinity of this singular acid for water? What is said of the action of this acid on the flesh? What is said of the action of fluoric acid on glass? Describe the method of making designs on glass.

the glass in a horizontal position, and pouring on the liquid acid. But a simpler method is by the temporary extrication of the gas from the fluor spar, for the occasion. For this purpose, take a lead or tin cup, large enough to include the figures on the glass, the lower the better, and having placed on its bottom a table spoonful of powdered spar, pour on it a quantity of strong sulphuric acid sufficient to form a paste. Then place the glass on the cup, as a cover, with the etching downward, and set the cup in a dish of hot water, or apply to it the gentle heat of a lamp, taking care not to melt the wax. In twenty or thirty minutes, the etching will be finished, and the wax may be removed with a little spirit of turpentine. In this manner, figures of any kind may be permanently and beautifully done on glass.

Since the above was written, the composition and affinities of fluoric acid have been more minutely examined, and more appropriate names affixed to its compounds.

Fluorine is the hypothetical base of the hydrofluoric acid. The latter is the present name of fluoric acid. Its composition is

1 eq. Fluorine, 18+1 eq. Hydrogen, 1=19.

374. FLUOBORIC ACID.—A gas made by heating to redness a mixture of dry boracic acid, and powdered fluor spar. It is colorless, pungent, and produces a dense white cloud, when it escapes into a moist atmosphere. It is probably composed of

1 eq. Boron, 11+6 eq. Fluorine, 108=119.

375. FLUOSILISIC ACID.—A gas obtained from a mixture of fluor spar and silex by the aid of sulphuric acid. The fluoric acid produced in the usual way is a fluosilisic, since fluor spar nearly always contains more or less silex. Its composition is

1 eq. Fluorine, 19+1 eq. Silicium, 8=27.

After the design is formed, in what manner is the etching done? What is hydrofluoric acid? What is the fluoboric acid? What is fluosilisic acid?

CHAPTER XVI.

COMBINATIONS OF SIMPLE NON-METALLIC COMBUSTIBLES WITH EACH OTHER.

CARBON AND HYDROGEN.

BICARBIDE OF HYDROGEN.

Equivalent, 8. Symbol, CH_2.

1 eq. Carbon, 6 + 2 eq. Hydrogen, 2.

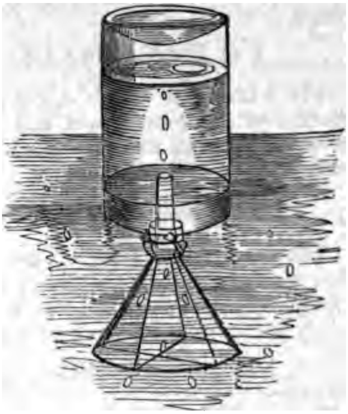
LIGHT CARBURETED HYDROGEN.

376. This gas has also been called *hydro-carburet*, and *light inflammable air.*

It exists in every stagnant pool of water, especially during the warm season, being generated by the decomposition of vegetable products.

377. How obtained.—To obtain it from such places, fill a glass jar with water, and invert it in a stagnant pool or ditch; then stir the mud under it with a stick, and the gas will rise and displace the water in the jar. To preserve it for examination, slide a dish under the mouth of the jar while in the water, and then carefully raise, and carry the whole to the place of experiment, or make use of a bottle and funnel, as shown by Fig. 96.

FIG. 96.



Gas from Stagnant Water.

378. Properties.—The gas so obtained is found to contain a proportion of carbonic acid gas, which may be removed by passing it through lime water.

What are the names under which carbureted hydrogen has been known? In what place has this gas been formed by the operation of nature? How may it be obtained from stagnant pools of water? What gas is commonly found mixed with this? What is the atomic composition of carbureted hydrogen?

This gas is composed by weight of

1 equivalent of carbon,	6
2 " " hydrogen,	2
	8

379. It is immediately destructive to animal life, and will not support combustion. It is highly inflammable, and burns with a yellowish blue flame, but owing to the carbon it contains, it gives considerably more light than pure hydrogen. Mixed with atmospheric air, like hydrogen, it detonates powerfully when inflamed. When burned with oxygen, the product of the combustion is water and carbonic acid.

There appears to be several varieties of light carbureted hydrogen, or perhaps the difference may depend on a mixture of the light and heavy kinds. If a volume of steam be sent through a red hot gun-barrel filled with charcoal, the gas obtained differs little in its illuminating powers from that obtained from stagnant pools. Nor is there any material difference between these and that evolved by the burning of common wood, such as maple or beech, in a gun-barrel. But if pine wood containing turpentine, be heated in the same manner, the gas obtained has much greater illuminating powers, the brilliancy of the flame being nearly equal to that of oil gas. Now, as by analysis there appears to be only two kinds, or varieties, of carbureted hydrogen; in the first of which there is but one proportion, and in the second two proportions of carbon, it is most probable that these different powers of illumination depend on a mixture of the two gases.

380. This gas sometimes exists in large quantities in coal mines, and is known by the miners under the name of *fire-damp.* The most shocking accidents have often occurred in consequence of the explosion of this gas in the mines, when mixed with atmospheric air. In some mines, this gas flows from the coal beds in vast quantities, being obviously the product of the decomposition of water by the coal. But in what manner the water is decomposed, is unexplained. Did the process consist in the formation of sulphuric acid, in consequence of the oxygenation of the sulphur, and the subsequent action of this acid on the iron of the sulphuret of iron,

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How does it effect animal life and combustion? When burned, why does this gas give a stronger light than pure hydrogen? What is said concerning the several varieties of carbureted hydrogen? Under what name is this gas known, when it occurs in coal mines? In what manner is this gas formed in coal beds?

there would be formed *sulphureted*, instead of carbureted hydrogen.

There are no facts, it is believed, which warrant the supposition, that in ordinary cases, the decomposition is consequent upon the heat, or ignition of the coal. Possibly in such vast bodies of coal as are found to exist in some mines, the water is slowly decomposed, by gradually imparting its oxygen to the carbon, without the aid of heat.

381. Explosive compound.—We have already stated, that when carbureted hydrogen is mixed with atmospheric air, and inflamed, a violent explosion is the consequence. In the coal mines of England, the mixture of atmospheric air and the gas in question, often produces such an explosive compound. It appears that the miners have no certain means of ascertaining the presence of this gas, probably because, being much lighter than the atmospheric air, it at first rises to the roof of the mine, and then gradually descends toward the floor. As the miners work entirely by the light of lamps, one of which is sufficient to set fire to the explosive compound existing throughout the whole cavern, it is obvious, that as soon as the hydrogen has mixed with the air near the floor of the mine, in the exploding proportions, it must inevitably take fire. It can readily be imagined, particularly by those who have witnessed the detonation of a pint or two of this compound, that a quantity covering many acres of surface, and extending upward in some places, at least, several hundred feet, must produce the most awful consequences.

382. Explosion in Felling colliery.—Such explosions have often taken place in the coal mines in different parts of England. That which happened in a mine called *Felling colliery*, in Northumberland, on the 25th of May, 1812, was attended with the loss of 92 lives, and spread poverty and wretchedness throughout the whole district. Most of these men had wives and children, who depended entirely on their daily labor for support, and who, in addition to the loss of their husbands and fathers, by so sudden and awful a death, were in a moment deprived of the means of subsistence.

This mine had been wrought a century or more, and only a single accident from fire-damp had before happened, and this

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What are the remarks on this subject? What is the consequence, when this gas is mixed with atmospheric air and inflamed? In what situations is it said that explosive compounds are thus formed? What is the reason that the miners are not aware of the existence of this compound until the whole takes fire? What number of lives were destroyed by such an explosion at Felling colliery, in 1812?

was so trifling, as only to slightly burn two or three workmen. Twenty-five acres of coal had been excavated in this mine, and the number of men employed under ground, at the time of the accident, was 128. The explosion took place between the hours of 11 and 12 in the morning. The fire was seen to issue from two shafts leading to the mine, and called *William* and *John*, and at the same instant, the noise of the explosion, which was heard three or four miles, and the trembling of the earth, showed that an awful accident had happened there.

The force of the expanded gas was such as to throw from the two shafts immense clouds of dust, and small coal, which rose high in the air, and also pieces of wood and working implements, which fell back near the shafts. As soon as the explosion was heard, the wives and children of the colliers came by hundreds to the place. But not a single person who was in the mine during the accident was to be seen. Terror and dismay was pictured on every countenance; some were crying out for a father, some for a son, and others for a husband.

383. The machinery for entering the mine, being shattered by the blast, it was at first impossible to go down, but the urgency of the occasion soon impelled those present to find the means of entering the shaft; and in about half an hour from the time of the explosion, 32 persons, all who remained alive out of 121, who were in the mine, were brought out. It appeared that of the whole number of the workmen, seven had come up, on different occasions, before the explosion, and were unhurt. The wives and children of those who were known to be still in the mine, waited in a most heart-rending state of anxiety, and those who had their friends restored, seemed to suffer nearly as much from excess of joy, as they had before done from suspense and grief. These hurried away with their friends from the dismal scene, while those who were still in suspense, or whose hopes ended in the dreadful certainty that their husbands or fathers were indeed among the dead, still lingered about the place, silently enduring the torture of a forlorn hope, and uttering cries of agony and despair.

384. As the fate of many of the men was still uncertain, because they were in different parts of the mine from those who had been found alive, the exertions of those above were unremitted, and in the course of an hour or two, many hundred people had collected around the shafts, all anxious to do every thing in their power for the sufferers. But it was soon found that the pit in some places was still on fire, the gas probably

continuing to burn as it was extricated from the coal. It was also found by those who attempted to descend, that where the mine was not on fire, it was filled with carbonic acid gas, the product of combustion, and that therefore it was impossible for any person to make further examination without inevitable death. Consequently all hope of finding any of the unfortunate persons alive, who were still in the mine, was abandoned, and it was proposed that the shafts should be closed, in order to extinguish the fire. But the wives and children of the sufferers, distracted at the idea of seeing their friends buried alive, and still entertaining hopes of their recovery, made the most pitiful importunities against such a course, while others became frantic with rage, and accused those of murder who proposed it. The owners of the mine, therefore, in mercy to the feelings of these distracted widows and orphans, waited until all were satisfied that no hopes remained of ever again seeing their friends alive, when the two shafts were closed with earth.

385. To insure the extinguishment of the fire, the mine was kept closed from the 27th of May until the 8th of July, on which day it was again opened and ventilated. On this occasion, the lamentations of the widows and orphans were again renewed, and such was the crowd of people that assembled on the spot, some urged by feeling and others by curiosity, that constables were in attendance to preserve order. Those who descended to search for the remains of these unfortunate sufferers, found no difficulty in breathing the air in the mine, but were struck with horror at the scene of destruction and mutilation, which the explosion had occasioned.

The search continued until the 19th of September, when 91 bodies had been found, brought up, and interred, but the 92d never was found.

We have been thus particular in describing a single instance of the awful effects of the fire-damp in mines, that the reader might fully appreciate the *safety-lamp*, an invention made by Sir Humphrey Davy, expressly for the purpose of preventing such explosions, and which has proved completely successful.

386. Invention of the safety-lamp.—Before the invention of this lamp, such explosions were more or less common, and all the mines were subject to them, though none has been attended with such destruction to human life as that of Felling colliery.

Does it appear that all excavated coal mines are liable to such accidents? What other accidents of the same kind are noticed? Who invented the safety-lamp, which protects the miners from such accidents?

In 1815, such an occurrence happened in a mine at Durham, and destroyed 57 persons, and in another mine, 22 persons were killed in the same manner.

The invention of the safety-lamp was not owing to accident, but is the result of inquiries undertaken and pursued expressly for the purpose of protecting the miners from such horrible accidents as we have described above.

Sir Humphrey Davy commenced his inquiries, by determining the proportions in which carbureted hydrogen and atmospheric air, in mixture, produce explosions; and found, that when the gas is mixed with three or four times its volume of air, it does not explode at all. When mixed with five or six times its bulk of air, it detonates, feebly, but when the air is in the proportion of seven or eight times the bulk of the gas, the explosion is most powerful; and with fourteen times its volume of air, it still explodes, though slightly. He also found that the strongest explosive mixture would not take fire when in contact with iron heated to redness, or even to whiteness; while the smallest point of flame, owing to its higher temperature, caused an instant explosion.

387. But the most important step in this inquiry was deduced from the fact that flame can not be communicated through a narrow tube. The fact itself was known before, but Sir H. Davy discovered, that the power of tubes, in this respect, is not necessarily connected with their lengths, and that a short one is as efficacious in preventing the transmission of flame, as a long one, provided its aperture be reduced in proportion to its length. Pursuing this principle, he found that fine wire gauze, which may be considered as an assemblage of exceedingly short tubes, was totally impermeable to flame; and on making the experiment, it was found that a lighted lamp, when completely surrounded with such gauze, might be introduced into an explosive mixture, without setting it on fire.

Thus, the means of preserving the miners, a most useful and laborious class of people, from the dreadful effects of the fire-damp, was at once developed. It only became necessary to surround their lamps with a fine net-work of brass wire, to in-

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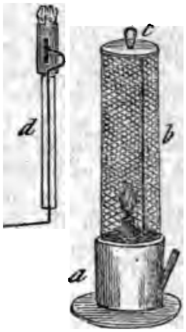
Was this invention accidental, or was the safety-lamp the result of inquiry and experiment ? In what proportions did Sir H. Davy find that carbureted hydrogen and common air exploded with the least force, and in what proportions with the greatest force ? What did Sir H. Davy discover in respect to the communication of flame through narrow tubes ? On pursuing this inquiry, what did Sir H. Davy discover with respect to wire gauze ? On this principle, how was it discovered that the miners might be protected from explosions ? In what manner do these lamps indicate the presence of danger ?

sure their safety from explosion. This lamp also indicates the existence of danger, for when the fire-damp in the mine is in a highly explosive state, it takes fire within the gauze, and burns there, while the light of the lamp itself is unseen. When the miners observe this indication of danger, they instantly leave the mine; for, although the flame within the gauze will not communicate with the explosive mixture on the outside, while the gauze is entire, yet as a high degree of heat would be kept up by the combustion within the lamp, the wire would soon become oxidated, and perhaps fall in pieces, when an instant explosion would be the consequence.

388. The safety-lamp is represented by Fig. 97. The cistern, *a*, holds the oil, and is in all respects a complete lamp, with a spout at the side, for feeding it. On the top of this is set the cylinder of wire gauze, *b*, supported by three iron or brass rods, to which is connected the disc, or cover, *c*, and to the cover, the ring or handle by which the whole is carried. The drawing, *d*, is a piece of wire passing through a tube, showing the manner in which the lamp is trimmed, and the wick raised, without making any dangerous communication between the outside and inside of the lamp. This tube passes through the cistern containing the oil.

FIG. 97.



Safety-lamp.

389. The reason why the wire gauze obstructs the communication of flame is easily explained. We have already stated, that according to the experiments of Sir H. Davy, the heat of flame is greater than that of a metal heated to whiteness, for the former occasioned a mixture of air and gas instantly to explode, while the iron, though white hot, produced no effect. Now the metals are all rapid conductors of heat; when, therefore, the flame comes in contact with the wire, its temperature is so reduced by the conducting power of the metal, as to be incapable of setting fire to the gas which is on the outside. Any one may illustrate this principle, by holding a piece of

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Why does it become necessary for the men to leave the mine, when the explosive mixture burns within the gauze? Describe the safety-lamp, as represented at Fig. 97, and point out the use of its several parts. Explain the reason why the flame is not communicated through the wire gauze. How may this principle be illustrated by holding a piece of wire gauze and the hand over a candle?

wire gauze over the flame of a lamp, and then bringing his hand over this, as near the lamp as he can bear. Now on removing the gauze, he will find that he can not for an instant bear the additional heat.

CARBURET OF HYDROGEN.

Equivalent, 28. Symbol, C_4H_4.

4 eq. Carbon, 24+4 eq. Hydrogen, 4.

OLEFIANT GAS.

390. To prepare this gas, mix in a capacious tubulated retort, three measures of alcohol, with eight measures of undiluted sulphuric acid, and then apply the heat of a lamp. This mixture turns black, swells, and emits bubbles of gas in abundance, which may be collected over water, in the same manner as described for hydrogen.

Alcohol is composed of carbon, hydrogen, and oxygen. During this process, the oxygen of the sulphuric acid appears to combine with a part of the carbon of the alcohol, in consequence of which, sulphurous acid gas is evolved, and the hydrogen is set free. At the same time, the hydrogen combines with another portion of the carbon, and escapes in the form of bicarbureted hydrogen. Or, perhaps, the evolution of the olefiant gas is owing to the strong attraction which the sulphuric acid has for the water which the alcohol contains, and by combining with which, the hydrogen and carbon are liberated.

Olefiant gas is colorless and elastic. It possesses no taste, and when pure, little smell, though, when not purified, it has a faint odor of ether. When mixed with oxygen and inflamed, it explodes with violence.

This gas is a little lighter than atmospheric air, 100 cubic inches weighing 29.64 grains. The weight of carbon in this composition is 25.41 grains, and the weight of hydrogen 3.23 grains.

Olefiant gas, therefore, consists of

		Grains.			
Carbon,	by weight,	24.31,	or two atoms,		12
Hydrogen,	"	4.23,	"	"	2
		29.64			14

How is olefiant or bicarbureted hydrogen gas obtained? What is the co of alcohol? What are the chemical changes which take place during the of olefiant gas? What are the sensible properties of this gas?

This gas may be decomposed, by passing it through a red hot porcelain tube, one proportion of carbon being deposited, in consequence of which it is converted into light carbureted hydrogen, which, as we have already seen, contains only 1 proportion of carbon to 2 of hydrogen.

GAS LIGHTS.

391. The olefiant gas, when pure, (with perhaps a single exception,) gives the most brilliant and intensely luminous flame of any known substance. The illuminating powers of other gases depend chiefly, if not entirely, on the olefiant gas they contain. In all cases, the light of any inflammable gas is in exact proportion to the quantity of carbon it contains.

The flame of pure hydrogen scarcely gives sufficient light to show the hour on a watch dial. When combined with one proportion of carbon, forming carbureted hydrogen, its light is greatly increased, and when combined with another proportion, its light becomes perfectly fitted for the purposes of illumination.

392. When first used.—Gas light, for the purpose of illumination, was first made and employed by Dr. Clayton, an Englishman, in 1739, but from some unknown cause, was given up, and neglected for sixty years afterwards. At length, Mr. Murdock instituted a series of experiments on the subject, and the gas distilled from coal began to be used, on a small scale, for lighting different factories in the vicinity of London.

From that period, which was about 50 years since, gas lights obtained from coal, or oil, have gradually come into use, for the purpose of lighting streets, shops, and manufactories, in all parts of Great Britain, and is, at the present time, in common use on the continent of Europe, and in most large towns in America.

For many years, the gas lights of London, and other parts of England, were supplied entirely by the distillation of bituminous coal, afterward impure oil, and, in some instances, rosin was used; but at present we believe bituminous coal is almost

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Does it explode when mixed with oxygen and inflamed? What is the weight of carbon, and what the weight of hydrogen, in this gas? What is the atomic composition, and what the combining number of this gas? How is olefiant gas decomposed and resolved into carbureted hydrogen? What is said of the brilliant light of the olefiant gas? On what does the brilliancy of gas lights depend? When were gas lights, for the purpose of illumination, first employed? From what substance was gas lights first obtained? What is the substance now employed in this country, and in some parts of England, for this purpose?

universally employed. In this country, the coal is imported from England.

393. Advantages of gas lights.—In respect to the advantages of gas, on the morals of society, in great cities, Mr. Gray, in his *Operative Chemist*, says: "From the more brilliant manner in which our streets (those of London) are lighted by gas, than they ever were or could be by oil or tallow, there is a greater degree of security, both in person and property, for every class of honest men. Crimes can not now be committed in darkness and secrecy; and as the risk of detection increases, the temptation to guilt is diminished, and thus coal gas, by the brilliant light it sheds on our streets, has worked, and is now working, a moral reformation. The house-breakers and pickpockets dread the lamps more than the watchmen, and a more efficacious measure of police was never introduced into society, than that from gas lights."

394. Gas works.—In large works, the gasometer is of immense size, being 40 to 60 feet in diameter, and 15 or 20 feet high, and capable of containing from 20 to 50,000 cubic feet of gas.

This is made of sheet iron, suspended by a chain, over a pulley, and counterbalanced by weights on the other side. This falls into a tank, or cistern, sunk in the ground. The tank being filled with water, the gasometer is let down into it, while the air escapes by opening a valve in its top. When the air is all excluded, the gas is conducted into the gasometer by a pipe coming from the retorts, and opening under the water. As the gas rises through the water, the gasometer is buoyed up, and rises also, and thus the vessel is filled with inflammable gas instead of air.

From the gasometer, which is the great fountain, the gas is conducted by one large iron pipe, laid under ground to the place or street where it is burnt. It is then conducted in smaller pipes through the different streets, and from these pipes it is conveyed to the houses and shops by small tubes; and tubes of still smaller size convey it to the burners where the lights are wanted.

The gas is measured by curious little machines called *meters*, one of which is in every house, and which indicate exactly the quantity consumed.

What is said of the influence of gas lights on the morals of London? How is oil gas manufactured? Describe the furnace and retorts. How is the oil admitted into the retorts? In large works, what is the size of the gasometer?

395. PORTABLE GAS.—As the burners are stationary, in the ordinary mode of lighting with gas, there exists an inconvenience in its employment for the purpose of common household illumination, where the lights are often necessarily carried to different parts of a room, or from one room to another. There is also another inconvenience, which arises from the expense of laying conductors through streets where the houses are scattered, and consequently, where but a small quantity of the gas is wanted. To remedy these defects in the ordinary method of lighting with gas, it has been proposed to condense the gas in strong copper, or brass lamps, at the gas works, and then transport them, thus filled, to the houses, to supply the place of common lamps. This is distinguished by the name *portable* gas, and has been extensively employed in London and its vicinity, but is now out of use.

396. ILLUMINATING POWER OF GAS.—The illuminating power of the oil gas is much greater than that of coal gas. According to the experiments of Mr. Accum, two cubic feet of coal gas will burn one hour, and give a quantity of light equal to three tallow candles, eight of which weigh a pound. But according to the experiments of Mr. Dewey, formerly superintendent of the gas works of New York, one cubic foot of oil gas will give light for one hour equal to 8 candles, 6 to the pound. This agrees very nearly with the result of Mr. Ricardo's experiments, who found that a given quantity of oil gas was equal in illuminating power to four times the same quantity of coal gas. One gallon of clean whale oil will make 100 cubic feet of gas, which, according to the above statement, will burn 100 hours, and give as much light as 8 mould candles, 6 weighing a pound. Such an immense difference between the cost of gas, and other lights, would seem to indicate the propriety of establishing gas works in every village. But the expenses of erecting and tending small establishments of this kind, are such as not to yield any considerable profit to the owners.

How is the gas conveyed into the gasometer? How is the gas conveyed from the gasometers to the gas burners? What inconvenience is experienced in the use of ordinary gas lights? How has it been proposed to remedy this defect? Under what name is this condensed gas known? Which gas has the greatest illuminating power, that from the coal, or that from oil? What is said to be the comparative difference between the illuminating power of coal and oil gas? What quantity of gas is it said one gallon of oil will make, and how long will this gas burn? The cost of oil gas being much less than other lights, why are they not universally used?

HYDROGEN AND SULPHUR.

SULPHIDE OF HYDROGEN.

Equivalent, 17. Symbol, SH.

1 eq. Sulphur, 16+1 eq. Hydrogen, 1.

397. This gas may be procured by placing in a retort some *sulphuret of antimony*, or iron, and pouring on it sulphuric or muriatic acid. The sulphurets of these metals may be prepared by heating either of them, in filings or powder, with sulphur; or the natural sulphurets may be employed. The chemical changes, concerned in the formation of this gas, are as follows: The oxygen of the water which the acid contains unites with the metal of the sulphuret, which metal is then dissolved by the acid. Thus, the hydrogen of the water, and the sulphur of the sulphuret, are both set at liberty, and having an affinity for each other, they combine, and escape in the form of sulphureted hydrogen.

398. Properties.—Sulphureted hydrogen is a transparent, elastic gas, which, both to the taste and smell, is exceedingly unpleasant and nauseous, its odor being similar to that of putrefying eggs. Under a pressure of 17 atmospheres, that is, under a weight equal to 255 pounds to the square inch, this gas is condensed into a colorless liquid, but again assumes its gaseous form, when the pressure is removed.

This gas is instantly fatal to animal life, when pure, and even when diluted with 1500 times its bulk of air, has been found so poisonous as to destroy a bird in a few seconds. Like hydrogen, it instantly extinguishes flame, but is itself inflammable, and burns with a pale blue flame. The products of its combustion are water and sulphuric acid. The composition of this gas being hydrogen and sulphur, the water formed during its combustion is the product of the union between the hydrogen and the oxygen of the atmosphere, during the act of combustion, while the sulphuric acid is formed by the union of the oxygen of combustion with the sulphur.

Sulphureted hydrogen tarnishes silver, and even gold, and blackens paint made with preparations of lead. This gas is

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How may sulphureted hydrogen be procured? What chemical changes take place by which this gas is evolved? What are the sensible properties of this gas? Under what pressure may this gas be condensed into a liquid? Does it remain liquid when the pressure is removed? What is said of the poisonous effects of this gas? What are the effects of plunging a burning candle into this gas? When this gas is burned, what are the products of combustion? Whence come the water and sulphuric acid? What is its effects on the metals?

often generated during the decomposition of animal products, in sink drains and ditches, and hence the paint of white lead, about such places, often becomes black in consequence. Eggs contain a small quantity of sulphur, which, on boiling, is converted into sulphureted hydrogen, and hence a silver spoon is instantly tarnished by coming in contact with a boiled egg.

The composition of sulphureted hydrogen by weight, is as follows:

100 cubic inches of this gas weigh	36	grains.
This is composed of sulphur, . .	33.39	"
" " " hydrogen, .	2.11	"
	36.00	

HYDROGEN AND PHOSPHORUS.

PHOSPHIDE OF HYDROGEN.

Equivalent, 35. Symbol, PH_3.

1 eq. Phosphorus, 32+1 eq. Hydrogen, 3.

399. This compound consists of hydrogen, in which is dissolved a small quantity of phosphorus. It may be formed in several ways. One of the most simple is the following: Into five parts of water put 15 or 20 grains of phosphorus, cut into small pieces. It must be cut under water to prevent its taking fire. Then add one part of granulated zinc, and pour in three parts of sulphuric acid.

The gas will instantly rise through the water in small bubbles, and will take fire spontaneously on coming in contact with the air. Each bubble, as it takes fire, will form a horizontal ring of white smoke, which will gradually enlarge as it rises, until lost in the air. The cause of this curious appearance is owing to the formation of a small quantity of phosphoric acid by the combustion of the phosphorus, and which, having a strong affinity for moisture, attracts it from the atmosphere, and thus forms a little ring of dew, which is visible to the eye.

Phosphureted hydrogen may also be obtained by placing some pieces of *phosphuret of lime* in water, when the gas will be extricated, and will rise through the water as above described. (*See Phosphuret of Lime.*)

What is the composition of 100 cubic inches of this gas by weight? How is phosphureted hydrogen formed? What singular property does this gas possess? How is the ring of white smoke accounted for, which rises after the combustion of a bubble of this gas?

This gas detonates with great violence when mixed with oxygen, and forms a dangerous explosive compound with atmospheric air; consequently, much caution is required in making experiments with it.

When a bubble of phosphureted hydrogen is allowed to mix with oxygen, a flash of the most vivid light is spontaneously produced, which, in a darkened room, resembles lightning. The safest method of performing this beautiful experiment, is to let up into a small strong bell glass, or a thick glass tube, a few ounces of oxygen gas. Then, having collected a little of the phosphureted hydrogen in a small vial, hold the bell glass in the left hand, with its mouth under water, and with the right hand manage the vial, so as to let only a single bubble at a time escape into the oxygen. The detonation of each bubble will produce a considerable reaction on the bell glass, which will be felt by the hand. But if the experiment be performed as described, there will be no danger of an explosion.

The gas above described is called *per-phosphureted hydrogen*, denoting, as already explained, the highest degree with which one body unites with another. It is so called to distinguish it from the *proto-phosphureted hydrogen*, which contains only half the quantity of phosphorus, and is a much less interesting compound.

Per-phosphureted hydrogen consists of

1 equivalent of phosphorus,	32
3 " " hydrogen,	3
	35

NITROGEN AND CARBON.

BICARBIDE OF NITROGEN.

Equivalent, 26. Symbol, C_2N.

2 eq. Carbon, 12+1 eq. Nitrogen, 14.

CYANOGEN.

400. By boiling together red *oxide of mercury* and *Prussian blue* in powder, with a sufficient quantity of water, there may be obtained a compound which shoots into crystals, and which was formerly called *prussiate of mercury*, but is now known by the name of *cyanuret of mercury*.

With what substances does phosphureted hydrogen afford dangerous detonating compounds? What directions are given for admitting bubbles of this gas into oxygen? What is the equivalent composition of per-phosphureted hydrogen? How may cyanuret of mercury be formed?

When this salt is heated in a retort, it turns black, the cyanogen passes over in the form of a gas, and the mercury is revived, or assumes its metallic form.

This gas has a pungent, disagreeable odor, burns with a purplish blue flame, extinguishes burning bodies, and is reduced to a liquid under the pressure of about three and a half atmospheres. This gas must be collected over mercury.

100 cubic inches of this gas weigh 55 grains, and is found to be composed of

2 equivalents of carbon,	12
1 " " nitrogen,	14
	26 its combining number.

Cyanogen, though a compound gas, has the singular property of combining with other substances, in a manner perfectly similar to the simple gases, such as oxygen and hydrogen.

The term cyanogen comes from two Greek words, signifying *to form blue*, because it is an ingredient in Prussian blue.

HYDROCYANIC ACID.

Equivalent, 27. Symbol, HCy.

1 eq. Cyanogen, 26+1 eq. Hydrogen, 1.

PRUSSIC ACID.

401. Cyanogen is obtained by simply heating cyanuret, or prussiate of mercury, as above described. Hydrocyanic, or prussic acid, is composed of cyanogen and hydrogen. It may be obtained by heating in a retort a quantity of prussiate of mercury with two-thirds of its weight of muriatic acid. During this process there takes place an interchange of elements. The cyanogen of the cyanuret of mercury unites with the hydrogen, forming hydrocyanic acid, while a muriate of the peroxide of mercury remains in the retort.

But a more common method of making prussic acid is the following:

402. **Process for prussic acid.**—Mix together, in a convenient vessel, four ounces of finely powdered Prussian blue, two

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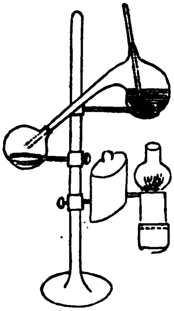
How is cyanogen procured? What are the properties of this gas? What is the equivalent composition of this gas, and what is its combining number? Whence comes the name of this gas? How may hydrocyanic, or prussic acid, be formed by means of prussiate of mercury and muriatic acid? What are the interchanges of elements which take place during this process? What is the more common method described for making prussic acid?

and a half ounces of red oxide of mercury, and twelve ounces of water. Boil the mixture for half an hour, now and then stirring it. The blue color will disappear, and the solution will become yellowish green. Filter the solution, and wash the residuum by pouring on boiling water, in quantities sufficient to make up the loss by evaporation, and let this also pass through the filter.

FIG. 98.



Prussic Acid.

Put this solution, which is a prussiate of mercury, into a retort containing two ounces of clean iron filings, then connect the retort with a receiver, and place them on a lamp furnace, as represented by Fig. 98, taking care that the juncture be made air-tight, which may be done by winding a wet rag around the neck of the retort. Next pour into the retort one ounce of sulphuric acid, diluted with three or four parts of water, and stop its tubulure by passing in a straight glass tube, which had been ready prepared by being passed through a cork. Then light the lamp, and distill with a slow heat, until three ounces of prussic acid is obtained. The receiver must be kept cold, and also from the light, by being covered with a wet cloth.

The fumes of this acid are exceedingly poisonous, and therefore the lamp furnace should be set in a fireplace during the process, so that they may escape up the chimney. There is a complicated interchange of principles which take place in this process, which Scheele explains thus: In Prussian blue the prussic acid exists in combination with iron. The red oxide of mercury having a stronger attraction for this acid than the iron has, the Prussian blue is decomposed, and a *prussiate of mercury* is formed, which is soluble in water. On the addition of the iron filings and sulphuric acid to this solution, the iron absorbs the oxygen from the mercury, which is then precipitated in the metallic form, and at the same instant the iron is thus oxidized, it is dissolved by the sulphuric acid forming the sulphate of iron. Thus, the prussic acid is liberated, because it does not combine with the metals, but only with their oxides, and as the iron de-

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What is said of the poisonous quality of the fumes of this acid, and of the precautions to avoid them? Explain carefully the complicated interchange of chemical principles that takes place by this process. What is the appearance of the acid thus obtained?

prives the prussiate of mercury of its oxygen, the prussic acid remains free in the solution of the sulphate of iron, and being volatile, readily passes over into the receiver, by a gentle heat.

The hydrocyanic acid thus obtained, is a perfectly colorless, limpid fluid, and can not be distinguished by the eye from distilled water. It has a strong odor, resembling that of peach blossoms, and when much diluted has the taste of bitter almonds.

403. A MOST DEADLY POISON.—Prussic acid is the most active and powerful of all known poisons. A single drop placed on the tongue of a dog causes his death in a few seconds; and a servant girl who swallowed a small glass of it, diluted with alcohol, fell down instantly, as though struct with apoplexy, and died in two minutes. A professor at Vienna, having prepared some of this acid in its most concentrated state, by way of experiment, diffused some of it on his naked arm, and was killed thereby in a short time.

These instances not only show the terrific and mysterious effect which this substance has on the animal economy, but they also show what extreme caution is necessary in preparing and using it. When much diluted, it has, however, been considerably employed as a medicine, in cases of consumption, and often with good effect.

404. OBSERVATIONS.—Although the investigations of chemistry have developed this substance, than which, even lightning itself is scarcely more prompt, or sure, in destruction, still the wisdom of Omniscience has connected circumstances with its production and nature, which, in a great measure, will always prevent its employment for criminal purposes. The process by which it is made, requires more chemical skill than generally falls to the lot of unprincipled and vicious persons; and when obtained, its active properties are so evanescent, as never to remain more than a week or two, without peculiar treatment, and sometimes it becomes nearly inert in a few days. The odor, also, which is distinguished in animals destroyed by it, is often the sure means of detection.

The commencement of its decomposition is marked by the reddish brown color of the liquid, and, in a short time after, it becomes black, and deposits a thick carbonaceous substance, at

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What is the smell of this acid? What cases are mentioned of its poisonous effects? For what purposes is this acid employed when much diluted? What circumstances are connected with the production and nature of this acid, which it is said will prevent its employment for wicked purposes?

the same time it loses its peculiar smell, and emits that of ammonia. In this state, the prussic acid has none of its former properties, but becomes entirely inert and worthless.

This substance possesses the sensible qualities of an acid only in a very slight degree, being hardly sour to the taste, and producing but very little change in the blue colors of vegetables. It however performs the office of an acid in combining with alkaline bases, forming salts, called *prussiates*, or *hydrocyanates*.

405. COMPOSITION OF.—The following is an example, by which the composition of a substance may be found, when one of its elements can be made to combine with a third body, in a known proportion. By a previous experiment it was ascertained how much cyanogen would combine with a given proportion of potassium, the basis of potash. Then, Gay Lussac exposed to the action of 100 measures of prussic acid, heated so as to be in a state of vapor, a quantity of potassium precisely sufficient to absorb 50 measures of cyanogen. By this process, cyanuret of potassium was formed, and exactly 50 measures of the vapor of prussic acid was absorbed, leaving 50 measures of pure hydrogen remaining in the vessel in which the experiment was made.

From this experiment, it appears that prussic acid is composed of equal volumes of cyanogen and hydrogen, and therefore that they combine in the ratio of their specific gravities, that is, the weight of the vapor of prussic acid must be the combined weights of cyanogen and hydrogen, of an equal bulk.

406. ATOMIC WEIGHTS OF.—Now the specific gravity of hydrogen is known to be 0.0694, and cyanogen gas, 1.8044, air being 1000. Cyanogen, therefore, is 26 times as heavy, bulk for bulk, as hydrogen, and since they combine in equal proportions, by volume, to form prussic acid, it follows that this acid consists of an atom of hydrogen united to an atom of cyanogen, and, therefore, that an atom of cyanogen gas is 26 times as heavy as an atom of hydrogen. Thus, the atomic weight of cyanogen is 26, that of hydrogen being 1, and the specific

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How does the acid appear while decomposing? Does this substance possess the sensible qualities of an acid? In what respect does it perform the office of an acid? How did Gay Lussac know that exactly 50 measures of cyanogen were absorbed by the potassium? [Cyanogen combines with metals in the same manner that oxygen does. See Cyanogen.] What was the quantity of hydrogen which remained after this absorption? From this experiment, what appears to be the composition of prussic acid, by volume; and therefore, the vapor of prussic acid consists of the combined weight of what? How does it appear that cyanogen is 26 times as heavy as hydrogen? [Multiply 0.0694 by 26.]

gravity of the vapor of prussic acid being the medium between them, is 0.9369, because 0.0694, the specific gravity of hydrogen, added to 1.8044, the specific gravity of cyanogen, makes 1.8738, the medium or half of which is 0.9369, the specific gravity of the vapor of prussic acid.

The composition of prussic acid may therefore be stated thus:

By volume.	By weight.	
Cyanogen, 50	1.8044	26, one atom.
Hydrogen, 50	0.0694	1, one atom.
100 acid vapor.		27 atomic weight.

Thus the atomic weight, or equivalent number for cyanogen is 26, and that for prussic acid is 27.

The above will serve as a practical example of the method of finding the atomic weight of a constituent, under similar circumstances.

CARBON AND SULPHUR.

SULPHIDE OF CARBON.

Equivalent, 38. Symbol, CS_2.
1 eq. Carbon, 6+2 eq. Sulphur, 32.

407. Preparation of.—This singular and interesting compound, as the name indicates, is composed of sulphur and carbon. These substances unite only in one proportion; by merely heating them together, no combination takes place, the sulphur burns away, or passes off in vapor, and the charcoal remains unchanged; but by bringing the vapor of sulphur into contact with charcoal at a red heat, the combination takes place immediately. For this purpose a porcelain tube is sometimes employed, but one of cast-iron, or a gun-barrel, coated with clay on the inside, is better. For this purpose, the clay is formed into a thin paste, with water, and poured into the tube, this being at the same time rolled so that the clay will cover every part. After one coat is applied, and dried by heating the tube, the same process is repeated, until the surface is well covered,

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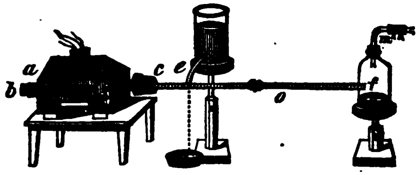
How does it appear that an atom of cyanogen is 26 times as heavy as one of hydrogen? [Because they combine in equal volumes, but cyanogen weighs 26 times the most.] What then is the weight of an atom of cyanogen, that of hydrogen being 1? What is the specific gravity of the vapor of prussic acid, it being the medium between those of cyanogen and hydrogen? From these data, what is the composition of prussic acid, by volume and weight? What is the equivalent number for prussic acid?

and the iron is thus protected from the action of the sulphur. If the tube is not well prepared, the experiment will fail entirely, since the action of the sulphur in a few moments would destroy the iron.

The tube, well covered, is filled with burning charcoal, and laid in the furnace, Fig. 99, until it attains a white heat. The end, *b*, of the tube is closed with a piece of clay, and at *a* there is an aperture for the admission of the sulphur; this is also furnished with a stopper of clay. A long glass tube, *o*, is attached to the iron pipe at *c*, and passes into the capacious flask, *f*, through an aperture in the side. In the absence of such a flask, a double necked bottle will do. A waste pipe, *m*, arises from the flask, and leads into the open air through a window, so as to avoid the fumes of the sulphur. At the bottom of the flask some water is placed, to receive the product of the experiment. The flask and glass tube should be kept cold during the whole process. For this purpose, the tube should be surrounded by a cloth kept wet with water from the cistern, *e*, and the flask surrounded with ice.

FIG. 99.



Preparation of Sulphide of Carbon.

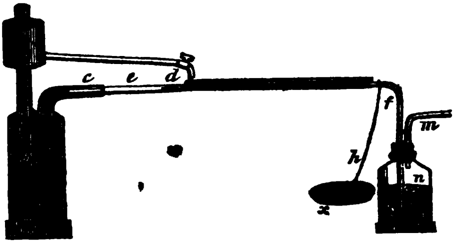
When the apparatus is ready, and the iron tube is at a white heat, the stopper *a* is to be removed, and pieces of sulphur dropped in, and the stopper instantly returned to its place. The sulphur instantly melts, and in passing through the hot tube, which is a little inclined, is converted into vapor, and at the same time unites with the charcoal, to form the compound in question.

The sulphuret of carbon, being condensed by the cold tube, flows along into the flask, and sinks in the water it contains.

408. ANOTHER METHOD.—A more simple method of producing the sulphuret of carbon, where it is designed to make it in quantities, is the following:

A cast-iron cylinder is produced, having a cover through which pass the tubes, *b*, *c*, Fig. 100. The cylinder is to be coated with clay in the manner above described for the iron tube, and then filled with charcoal, the tube, *b*, being in its

FIG. 100.



Sulphide of Carbon.

place as shown by the figure. The cylinder is then to be placed in a furnace, and heated to redness, and then the sulphur introduced through the tube, *b*, the aperture of which must be immediately closed. The melted sulphur, passing down the tube to the bottom of the cylinder, is there converted into vapor, and passing through the ignited charcoal combines with it, and rises by the iron tube, *c*, into the glass tube, *e*, along which it is condensed. The tube, *d*, leads from a cistern of water, which is allowed in small quantities to run in a trough containing the glass tube, and from which it is conducted by the string, *h*, to the dish, *x*. The sulphuret as it is formed, passes down the tube, *f*, into the vessel, *n*, this being half filled with pounded ice. The waste pipe, *m*, conducts away any superfluous gas which is generated during the process.

Whenever all is prepared, as above described, the introduction of small quantities of sulphur by the tube, *b*, will insure the production of the compound in question, so long as any charcoal remains in the cylinder. It is apt, however, to contain some impurities, and must be distilled with chloride of calcium.

409. PROPERTIES.—Pure sulphuret of carbon is transparent and colorless, and insoluble in water. It has a strong, disagreeable smell, peculiar to itself, and is soluble in alcohol, and ether. Its specific gravity is 1.272, and it boils at 127 degrees, evaporating very rapidly during the process. Its freezing point is 60

degrees below zero. In the open air, it is exceedingly volatile, and the cold it thus produces is intense. Under the exhausted receiver of the air-pump, the evaporation of course is still more rapid. In this situation, a thermometer bulb, covered with fine lint, and moistened with this fluid, carried off the heat so rapidly by evaporation, that the mercury was frozen in the tube, and and on substituting an alcohol instrument, the fluid sunk down to 80 degrees below zero. Sulphuret of carbon is soluble in fixed and volatile oils, and it dissolves camphor, phosphorus, and sulphur. When the two latter substances are dissolved in it separately, the evaporation of the fluid causes crystals of them, of remarkable regularity and beauty, to be deposited.

CHAPTER XVII.

THE METALS.

TABLE OF THE DISCOVERY OF THE METALS.

Names of metals.	Authors of the discovery.	Dates.
Gold,	Known to the ancients.	
Silver,		
Iron,		
Copper,		
Mercury,		
Lead,		
Tin,		
Antimony,	Described by Basil Valentine,	1490
Bismuth,	Described by Agricola,	1530
Zinc,	First noted by Paracelsus,	16th century.
Arsenic,	Brandt, the chemist,	1733
Cobalt,		
Platinum,	Wood, assay-master, Jamaica,	1741
Nickel,	Cronsted,	1751
Manganese,	Gahn and Scheele,	1774
Tungsten,	Dr. Elhuyart,	1781
Tellurium,	Muller,	1782
Molybdenum,	Heilm,	1782
Uranium,	Klaproth,	1789
Titanium,	Gregor,	1791
Chromium,	Vauguelin,	1797
Columbium,	Hatchett,	1802
Palladium,	Wollaston,	1803
Rhodium,		
Iridium,	Descotils and Tennant,	1803
Osmium,	Smithson Tennant,	1803
Cerium,	Hissinger and Berzelius,	1804

TABLE OF THE DISCOVERY OF THE METALS.—CONCLUDED.

Names of metals.	Authors of the discovery.	Date.
Potassium,	Sir Humphrey Davy,	1807
Sodium,		
Barium,		
Strontium,		
Calcium,		
Cadmium,	Stromyer,	1818
Lithium,	Arfwedson,	1818
Zirconium,	Berzelius,	1824
Aluminum,	Wohler,	1828
Glucinum,		
Yttrium,		
Thorium,	Berzelius,	1829
Magnesium,	Bussy,	1829
Vanadium,	Sefstrom,	1830
Lanthanium,	Mosander,	1839
Didymium,	Mosander,	1840
Erbium,		
Terbium,		
Rutherium,	Klaus,	1844
Pelopium,	H. Rose,	1846
Niobium,		
Donarium,	Bergman,	1848

GENERAL PROPERTIES OF THE METALS.

410. The metals form the most numerous class of undecomposed, or elementary bodies. They possess a peculiar luster, called the *metallic*, which continues in the streak, or when they are reduced to small fragments. They are all conductors of electricity and caloric. They are fusible, at different temperatures, and in fusion retain their luster and opacity. They are, in general, good reflectors of light, and with the exception of gold, which, in the thinnest leaves transmits a green light, they are perfectly opaque.

Many of the metals may be extended under the hammer, and are hence called *malleable*, or under the rolling press, and are called *laminable*, or may be drawn into wire, and are called *ductile*. Others can neither be drawn into wire, nor hammered into plates, but may be ground to powder in a mortar; these are called *brittle* metals.

The metals are capable of combining with each other, in any

Have any of the metals been decomposed ? What is the peculiar luster of the metals called ? What imponderable agents do all the metals conduct ? Are all the metals opaque ? What are malleable, laminable, and ductile metals ? What are brittle metals ? What is an alloy ? What is said of the specific gravity of the metals ? What are the properties in respect to which the metals differ ?

proportion, when melted together, and such compounds are called *alloys*.

With a few exceptions, the metals have the greatest specific gravity of all bodies. Potassium and sodium swim on water, but with these exceptions, the lightest among them, cerium, is about 5½ times the weight of water; platinum is more than 20 times heavier than the same bulk of water.

The metals differ in respect to brilliancy, color, density, hardness, elasticity, ductility, tenacity, conductility for caloric and electricity, fusibility, expansibility by heat, stability, odor, and taste.

411. Metals positive electrics.—When combined with oxygen, chlorine, iodine, or sulphur, and the resulting compounds submitted to the action of galvanism, the metals without exception are revived, and appear at the negative side of the battery, hence all the metals are *positive electrics*.

The malleable metals, such as gold, silver, and iron, in whatever manner their surfaces are increased, if this is done rapidly, grow hot, and crumble under the hammer, or press, and finally refuse to be extended any further. It then becomes necessary, if their surfaces are to be further extended, to *anneal* them, which is done by exposure to a red heat, when they become soft and malleable as before. It is probable that this change is produced by a quantity of caloric which the metal retains in its latent state, and by which its particles are prevented from forming so compact a mass as before. When the metal is again drawn under the hammer, or press, it grows hot, and at the same time is increased in density and specific gravity, the caloric before absorbed being given out, and the metal is again rendered brittle by the process.

412. All the metals become fluid by heat.—All the metals are converted into a fluid state by sufficient degrees of heat. In this respect there is a vast difference in the different metals. Mercury is a fluid at all common temperatures, and does not assume the solid form unless exposed to a temperature nearly 40 degrees below the freezing point, while platina and columbium continue solid under the highest heat of a smith's forge, and only become fluid under the heat of a compound blow-pipe, or the action of the most powerful galvanic battery.

What is the electrical state of the metals? When the surfaces of the malleable metals are suddenly increased, what effect is thereby produced on their temperature? When is it necessary to *anneal* a metal? How is the process of annealing supposed to affect the metal, so as to restore its malleability? By what means may all the metals be rendered fluid? What is said of the different temperatures at which the metals become fluid?

TABLE OF THE FUSIBILITY OF THE METALS.

FUSIBLE BELOW A RED HEAT.

	Fahr.		Fahr.
Mercury,	39 deg.	Lead,	594 deg.
Potassium,	136 "	Tellurium,	620 "
Sodium,	190 "	Zinc,	773 "
Tin,	442 "	Antimony,	800 "
Bismuth,	497 "	Cadmium,	442 "

INFUSIBLE BELOW A RED HEAT.

Silver,	2283 deg.	Iron, (cast,)	3479 deg.
Copper,	1996 "	Cobalt,	2800 "
Gold,	2016 "		

REQUIRE THE HEAT OF A FORGE.

Iron, (malleable,)
Manganese,
Nickel,
Palladium.

REQUIRING THE COMPOUND BLOW-PIPE.

Molybdenum,
Uranium,
Tungsten,
Chromium,
Titanium,
Osmium,
Iridium,
Rhodium,
Platinum,
Columbium.

413. METALS BECOME OXIDES.—With several exceptions, these bodies suffer a singular change on exposure to air and moisture, or on exposure to air and heat. They lose their tenacity, brilliancy, and other qualities peculiar to the metals, soil the fingers, and crumble to powder, but at the same time increase in weight. This change is termed *oxidation*, and in this state they are termed *metallic oxides.*

This increase in weight and loss of metallic splendor, does not happen when the metal is placed in a vacuum, or when it is protected from the air by varnish or other means, but is found to be the consequence of the union between the metal and the oxygen of the air, or water, or both. Thus, iron, when exposed to air and moisture, spontaneously absorbs oxygen, and is converted into a brown friable matter called *rust.* This is an *oxide* of iron. The increase of weight is caused by the solid oxygen which thus combines with the metal.

The metals, with the exception of platina, gold, and silver, are said to suffer a peculiar change, when exposed to heat, or to air and moisture? To what is this change owing, and what are the resulting compounds called? What causes iron and other metals to rust, when exposed to the air?

414. **The metals combustibles.**—The metals, in the language of chemistry, are termed *combustibles*, because they are capable of combining with oxygen, and thus passing through the process of oxidation, or combustion. In ordinary combustion there is an extrication of heat and light, and under favorable circumstances, several of the metals exhibit these phenomena. Zinc burns with a brilliant flame when heated, and exposed to the open air; and iron, when heated in oxygen gas, emits the most vivid scintillations, attended with intense heat. Gold and platina, the metals which have the least affinity for oxygen, are still capable of uniting with it so rapidly, as to produce scintillations when heated with the flame of the compound blow-pipe. In all cases the metals combine with oxygen most rapidly when exposed to the highest degrees of heat. Hence, at common temperatures, their oxidation proceeds so slowly as not to emit sensible light or heat; and some of them, such as gold, silver, and platina, do not combine with it at all at such temperatures.

Some of the metals combine with oxygen in only one proportion, while others combine with it in three or four proportions. Thus, there is only a single oxide of zinc, but there are three or four oxides of iron.

415. **Reduction of the metals.**—After the metals are converted into oxides, they may again be *reduced*, that is, brought back to their metallic states, by depriving them of their oxygen. This may be done by several methods, depending on the nature of the metal, or the force by which it retains the oxygen. The reduction of many of the metals from their ores, is nothing more than depriving them of their oxygen.

For this purpose, a common method is to heat the oxide with some combustible which has a stronger affinity for the oxygen than the metal has. Thus, the oxide parts with its oxygen, and assumes the metallic form, while the combustible absorbs that which the oxide before contained, and is itself consumed, or converted into an oxide. As an example, carbon, when heated, has a stronger affinity for oxygen than iron, and therefore, when carbon and oxide of iron are strongly heated together, the iron

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Why are the metals termed combustibles in the language of chemistry? Under what circumstances do several of the metals exhibit the ordinary phenomena of combustion? Under what circumstances do all the metals combine must rapidly with oxygen? What metals do not combine at all with oxygen at common temperatures? Do the metals all combine with the same proportion of oxygen? After a metal has been converted into an oxide, how may it again be reduced, or brought again to its metallic state? By what method can the metals be deprived of their oxygen? What is one of the most common methods of reducing iron from its ores? When iron is reduced by heating its oxide with charcoal, what becomes of the oxygen?

is reduced while the charcoal is converted into an oxide, or an acid, and passes away into the air, or in common language, is burned up. This is the method of reducing iron from its ores.

In some instances, heat alone drives away the oxygen and reduces the metal; but in such cases the metal has only a weak affinity for oxygen. The oxides of gold, mercury, and platina, are thus reduced.

Metals having stronger affinities for oxygen, resist such methods of reduction, and require the more powerful agency of galvanism. When metallic oxides are exposed to this influence, the reduced metal is found at the negative side of the battery, while the oxygen rises through the water at the positive side.

416. THE METALS NOT SOLUBLE IN THEIR METALLIC STATE.—None of the metals are soluble in an acid, in their metallic states, but when first combined with oxygen they are readily dissolved. Gold will not dissolve in muriatic acid alone, because this acid does not part with its oxygen with such facility as to form an oxide of the metal. But if a quantity of nitric acid be added to the muriatic, the gold instantly begins to enter into solution, and a chloride of the metal is formed. If a piece of zinc be thrown into sulphuric acid, it will remain undissolved, but if three or four parts of water be poured in, the metal is attacked with great violence, and soon dissolved. In this case the water furnishes the oxygen, by which the zinc is oxydized, and it is then dissolved by the acid. By this method hydrogen is obtained; the metal decomposing the water by absorbing its oxygen, while the hydrogen is set at liberty.

The metals combine with phosphorus, sulphur, and carbon, forming compounds called *phosphurets*, *sulphurets*, and *carburets*, or *phosphides*, *sulphides*, and *carbides*.

417. COMBINATION WITH SULPHUR.—Of all the inflammable bases, sulphur appears to possess the strongest affinity for the metals, and its combination with some of them is attended with remarkable phenomena. This affinity is shown by the following interesting experiment: Introduce into a Florence flask, three parts of iron, or copper filings, and one part flowers of sulphur,

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In what instances does heat alone reduce the metallic oxides? When metallic oxides are reduced by means of galvanism, at which pole of the battery is the oxygen extricated? Are any of the metals soluble in the acids, while in their metallic states? Why is it necessary to add nitric acid to the muriatic acid before it will dissolve gold? Why does not zinc dissolve in strong sulphuric acid? Why is hydrogen evolved when the zinc is dissolved in diluted sulphuric acid? When a metal combines with phosphorus, what is the resulting compound called? What is the composition of a sulphuret? What is the composition of a carburet? What combustible body appears to posses the strongest affinity for the metals? What experiment is stated, illustrating the affinity between iron and sulphur?

well mixed together. Then stop the flask with a cork, and place it over a lamp, so as to heat it slowly, and as soon as any redness appears, remove the flask from the fire. The chemical action thus begun, will be continued by the heat evolved by the combination between the sulphur and the metal, and the whole mass in succession will become red hot, which, in the dark, will produce a very beautiful appearance.

We have stated, in a former part of this work, that when bodies pass from a rarer to a denser state, caloric is evolved.

The heat and light, in this experiment, seems to be the consequence of this general law of condensation, for the sulphuret, formed by the union of the two bodies, occupies much less space than the metal and sulphur did before.

Many of the metallic sulphurets are very abundant in nature, forming the ores of the metals. Several metals are extracted entirely from such ores. The most abundant sulphurets are those of lead, antimony, copper, iron, and zinc.

The phosphurets are seldom found as natural products, but may be formed, by bringing phosphurets into contact with the metal, at a high temperature.

Carbon unites with iron in several proportions. Unrefined iron, steel, and black lead, are all carburets of iron, the latter containing 95 per cent. of carbon.

418. METALLIC SALTS.—When the oxide of a metal is dissolved in an acid, there is a compound formed, which differs entirely from either of these two substances, and when the liquor is evaporated there remains a crystalline solid, called a *metallic salt*. These salts differ materially from each other, according to the kind of acid and metal of which they are composed. Some of them, such as the sulphate of iron and acetate of lead, are of great importance to the arts.

The oxides of the metals readily unite, by fusion, with glass, and it is by such means that this substance is made to resemble gems and precious stones. The stained glass, so celebrated among the ancients, and used in the windows of churches, was prepared in this manner. This art was said to have been lost, but stained glass is still made in many parts of Europe, and in this country. (*See Glass.*)

419. ALLOYS OF THE METALS.—Compounds, made by fusing

Whence does the heat arise in this experiment? What are the most abundant sulphurets in nature? Are the phosphurets often found native? What carburets are mentioned? What is a metallic salt? What particular salts are mentioned, as being of great importance to the arts? What is said of the union between the metallic oxides and glass? What are alloys?

two or more metals together, are called *alloys*. In these cases there is a chemical union between the metals; and hence such compounds differ greatly from the metals of which they are composed. In general, the specific gravity of the alloy is greater than the medium specific gravity of the two metals, and of consequence, the bulk of the alloy is less than that of the two metals taken separately. As an example, if two bullets of copper and two of tin, of equal bulk, be melted together, they will form little more than three bullets of the same size. This diminution of bulk is accounted for, by supposing that the particles of the two metals enter into a closer union with each other, when combined, than those of either did in a separate state.

The alloys of the metals are also more easily fusible than the metals of which they are composed; that is, the melting point of an alloy is below the medium temperature at which the metals composing it are fusible.

420. Fusible alloy.—An alloy, made of 8 parts bismuth, 5 lead, and 3 tin, is a curious instance of this fact. In a separate state, the melting point of lead is 594 degrees, bismuth, 497 degrees, and tin, 442 degrees, and yet, when these are fused together, the compound melts at 212 degrees. Amusing toys, in the form of tea-spoons, have been made of this alloy. Such spoons, in the hand of those who know nothing of their composition, have excited great astonishment, by coming out of a cup of hot tea, with their bowls melted off.

The number of metals, and the variety of properties which they possess, render it necessary to throw them into classes and orders, that a knowledge of these properties may be more easily obtained.

SPECIFIC GRAVITY OF THE METALS.

AT 60 DEGREES FAHRENHEIT.

Platinum, ...	20.98	Uranium, ...	9.00
Gold, ...	19.26	Copper, ...	8.89
Tungsten, ...	17.60	Cadmium, ...	8.60
Mercury, ...	13.57	Cobalt, ...	8.54
Palladium, ...	11.30	Arsenic, ...	5.88
Lead, ...	11.35	Nickel, ...	8.28
Silver, ...	10.47	Iron, ...	7.79
Bismuth, ...	9.82	Molybdenum, . . .	7.40

In what respect do alloys differ from the metals of which they are composed? How is the increased specific gravity of the alloys accounted for? What is said of the fusibility of alloys? What curious illustration of the fusibility of an alloy made of bismuth, lead, and tin, is given?

Tin,	7.29	Tellurium,	6.11
Zinc,	6.86	Titanium,	5.30
Manganese,	6.85	Sodium,	.972
Antimony,	6.70	Potassium,	.865

CHAPTER XVIII.

CLASSIFICATION OF THE METALS.

421. **The** following arrangement is that originally proposed by Thenard, and adopted by Henry and others.

We have already stated, that some of the metals are reduced from the state of oxides by heat alone, such metals having only a slight affinity for oxygen. Others, it was also stated, have so strong an attraction for oxygen, that they can not be reduced by this method, but require the presence of a combustible, or some other means, for their reduction. The arrangement into classes is founded on this distinctive difference. The orders of the second class are founded on the powers of the metals to decompose water.

CLASS I.

Metals, the oxides of which are reducible to the metallic state, by heat alone. These are

Mercury,
Silver,
Gold,
Platinum,
Palladium,
Rhodium,
Osmium,
and
Iridium.

CLASS II.

Metals, the oxides of which are not reducible to the metallic state by the action of heat alone.

Order 1.—*Metals which decompose water at common temperatures.* These are

Potassium,
Sodium,
Lithium,
Barium,
Strontium,
Calcium.

What is the distinctive difference between the metals, on which is founded the arrangement into classes? What are the peculiar properties on which the orders of the second class are founded? How are the classes and orders defined, and what are the names of the metals belonging to each? How many metals belong to the first class, and how many to the second? What is the definition of class first?

ORDER 2.—*Metals which are analogous to Order* 1. They are the metallic bases of the earths. These are

Magnesium,
Yttrium,
Zirconium,
Glucinum,
Aluminum,
Silicium.

ORDER 3.—*Metals which decompose water at a red heat.* These are

Manganese,
Iron,
Nickel,
Zinc,
Tin,
Cadmium.
Cobalt,

ORDER 4.—*Metals which do not decompose water at any temperature.* These are

Arsenic,
Uranium,
Titanium,
Molybdenum,
Columbium,
Bismuth,
Chromium,
Vanadium,
Copper,
Tungsten,
Lanthanium,
Tellurium,
Antimony,
Cerium,
Didymium,
Lead,
Terbium,
Pelopium,
Erbium,
Rutherium,
Donarium.
Niobium,

The seven last metals in *Order* 4 are new, and have not, many of them, been so examined as to decide whether they belong to that order or not. They are, however, left there until we obtain more light on the subject. It will be seen by the catalogue of elements, that only a part of their combining numbers are known.

Of the first class, there are 8 metals; of the second, there are 41, making 49 in all.

CLASS I.

Metals, the oxides of which are decomposed by the action of heat alone.

MERCURY, (HYDRARGYRUM.)

Equivalent, 100. Symbol, Hg.

422. Mercury, or quicksilver, is found native, or in its pure state, only in small quantities, the mercury of commerce being chiefly extracted from *cinnabar*, which is a sulphuret of the

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From what substance is the mercury of commerce extracted? What is the composition of cinnabar, and what its chemical name? What is the method of obtaining the mercury from its sulphuret?

metal. The metal is extracted from this ore, by heating it in iron retorts, mixed with iron filings, or lime. By this process, the sulphur combines with the lime, or iron, forming a sulphuret of lime, or iron, while the mercury is volatilized, and is distilled into a receiver, where it condenses in its pure form.

This metal is distinguished from all others by preserving its fluidity at common temperatures. Its specific gravity is 13.5. At the temperature of 660 degrees it boils, rises in vapor, and may be distilled from one vessel into another. At 40 degrees below zero it becomes solid, and is then malleable, and may be hammered into thin plates.

When pure, this metal is not readily oxidized in the open air at common temperatures, but when mixed with other metals, such as tin, or zinc, there is commonly a film of oxide on its surface; hence, this is an indication that the mercury is impure. When mercury is triturated with an equal quantity of sulphur, there is formed a black powder, called *ethiops mineral.*

423. COMBINATION.—Mercury readily combines with gold, silver, tin, bismuth, and zinc; but not so readily with copper, arsenic, and antimony, and with platina and iron scarcely at all. The resulting compounds between mercury and the other metals are called *amalgams.*

Mercury has such an affinity for gold and tin as to dissolve these metals in small pieces, at common temperatures. In the mines of South America, a great proportion of the gold was formerly procured by amalgamation. Sand, containing particles of gold, was agitated in a close vessel with mercury, and the two metals thus brought in contact, united and formed an amalgam. This was then distilled in an iron vessel, by which the mercury was driven away, while the gold remained.

At the present time, the gold-beaters make use of the same means to obtain the small particles of the metal contained in the sweepings of their shops. The sweepings being placed in a close vessel, and agitated with mercury, an amalgam is formed. The gold is then separated by pressing the amalgam in a buckskin bag, which forces the mercury through the pores of the leather, while the gold is retained.

What striking distinction is there between mercury and other metals? What is the specific gravity of mercury? At what temperature does mercury boil, and at what temperature does it freeze? When solid, what property common to many other metals does it possess? What are the obvious indications of impurity in this metal? What is ethiops mineral? When mercury combines with other metals, what is the compound called? How is gold obtained by mercury? How do gold-beaters obtain the small particles of gold from among the sweepings of their shops?

Mercury is applied to many other uses in the arts, and is a constituent in several important medicines.

424. SILVERING LOOKING-GLASSES.—The *silvering* on the backs of looking-glasses is an amalgam of tin, and is put on in the following manner: A sheet of tin foil is laid perfectly smooth on a slab of marble, and on the tin foil, mercury is poured, until it is about the eighth of an inch thick; the attraction of the metals for each other, keeping the mercury from running off. When the mercury is spread equally over the surface, the glass plate is run or slid on. This is so managed by partly immersing the end of the plate in the edge of the mercury, and pushing it forward, as to entirely exclude the air from between the metal and the glass. Weights are then laid on the plate to press out the mercury, which does not amalgamate with the tin. In about 24 or 36 hours the amalgam adheres to the plate in the manner we see it on looking-glasses. The glass, therefore, merely serves to keep the amalgam in its place, and being transparent, to transmit the image which is reflected from the surface of the metal. Could the mercury be kept from oxidation, and be retained in its place without the glass plate, such mirrors would be much more perfect, since the glass prevents some of the rays of light from passing to and from the metal.

425. PERMEABILITY OF METALS TO MERCURY.—It has long been known that several metals, as tin, lead, and zinc, when dipped in mercury, would absorb a portion of that metal, and that the latter would rise in the former above its own level, perhaps, on the same principle, that water rises in bibulous substances, by what is called capillary attraction.

Prof. Henry, of the Smithsonian Institute, after various experiments on this curious subject, discovered the interesting fact that a bar of lead bent into the form of a syphon, would act as a real syphon on the mercury. Thus, when such a bar is placed with its shorter division in a vessel of that metal, the mercury will rise over the side of the vessel, and drop from the end of the longer division, thus exhibiting the syphon experiment, with a solid bar of metal for the tube, and mercury for the liquid.

In respect to the facility of transmission, it was observed that the mercury rose much more rapidly in cast, than in hammered lead, probably because the hammering closed the pores, thus

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What is the composition, called the silvering, on the backs of looking-glasses? Describe the process of silvering a plate of glass. In forming a looking-glass, what is the use of the glass plate?

rendering it less permeable than the cast lead. Mercury also penetrates tin, and exhibits with it the syphon action more readily than with lead. Several other metals also exhibit the same phenomena, with various degrees of rapidity.

The curious reader will find much more on this singular discovery by consulting Prof. Horsford's paper, read before the association at Albany.

MERCURY AND OXYGEN.

PEROXIDE OF MERCURY.

Equivalent, 116. Symbol, HgO_2
1 eq. Mercury, 100+2 eq. Oxygen, 16.

RED PRECIPITATE.

426. This compound is commonly formed by dissolving mercury in nitric acid, and then exposing the nitrate to such a degree of heat as to expel all the acid. It is in the form of small, shining crystalline scales, of a red color. When exposed to a red heat, this oxide is reduced, and converted into oxygen, and metallic mercury, a circumstance on which its arrangement in the present class depends. When long exposed to the action of light, the same effect is produced. Red precipitate is employed in medicine chiefly as an escharotic.

It will be observed at the head of this section, that the peroxide of mercury is composed of 100 parts of the metal, combined with 16 parts or two equivalents of oxygen. The protoxide of this metal consists of 100 mercury, and 8 oxygen, these compounds conforming precisely to the doctrine of definite and multiple proportions, as formerly explained. The reason why so large a number as 100 is taken for the equivalent of mercury, and some other metals, will be understood when it is recollected that the data from which all the proportional numbers are estimated, is the proportions of hydrogen and oxygen forming water. The proportion of oxygen in this compound being 8, and this number for oxygen being fixed, that for mercury is 100, because it is found by experiment, that these are the smallest proportions in which these two bodies combine.

What is the composition of peroxide of mercury? By what simple process is it obtained? How may this oxide be decomposed? What is the use of red precipitate? Explain the reason why the combining number for mercury is 200. What is said of the combination between mercury and the gas chlorine, at common temperatures? What common name has the protochloride of mercury? How does the protochloride differ from the bichloride of mercury? What is the common name for the bichloride of mercury?

MERCURY AND CHLORINE.

SUBCHLORIDE OF MERCURY.

Equivalent, 236. Symbol, Hg_2Cl.

2 eq. Mercury, 200+1 eq. Chlorine, 36.

CALOMEL.

427. When chlorine, a gas formerly described, is brought into contact with mercury, at common temperatures, a combination takes place between them, amounting to one proportion of each, forming a protochloride of the metal. This, however, is not the common method of preparing calomel; the two constituents being more conveniently combined in their proper proportions, by mixing the bichloride of this metal with an additional quantity of mercury. The bichloride of mercury contains, as its name signifies, two proportions of chlorine and one of the metal. This compound is known under the name of *corrosive sublimate*. It contains mercury 200, and chlorine 72 parts by weight. When this salt is triturated with mercury, the metal absorbs a part of the chlorine, and the whole is converted into a protochloride, or calomel. The proportions are 172 parts, or 1 equivalent of the corrosive sublimate, and 100 parts, or 1 equivalent of the mercury. This process affords a beautiful illustration of the truth of the doctrine of definite proportions; for when these equivalents are mixed in a mortar, and then sublimed by heat, 36 parts, or 1 proportion of the chlorine is transferred from the bichloride to the metallic mercury, thus converting the whole into 272 parts of protochloride of mercury, or calomel.

This process also shows, in a striking manner, the effects of different proportions of the same principles, on the qualities of bodies. Corrosive sublimate is one of the most active and virulent of all metallic poisons, and in doses of only a few grains, occasions the most agonizing symptoms, which commonly end in death. But calomel is a mild and safe medicine, which may be taken in doses of 60, or even 100 grains, without injury. And yet the only chemical difference between these two substances is, that the calomel is a compound of 1 atom of chlorine combined with 1 of mercury, while corrosive sublimate consists of 2 atoms of the first and 1 of the metal.

What is the common mode of making calomel? What proportions of corrosive sublimate and mercury combine and form calomel? What two principles are strikingly illustrated by this combination?

MERCURY AND SULPHUR.

SULPHIDE OF MERCURY.

Equivalent, 116. Symbol, HgS.

1 eq. Mercury, 100+1 eq. Sulphur, 16.

CINNABAR.

428. Cinnabar is prepared by fusing mercury and sulphur together, and afterward subliming the compound. When this compound is reduced to a fine powder, it forms the well known pigment *vermillion*. Cinnabar occurs in nature, in large quantities, and is the substance, as already stated, from which mercury is chiefly obtained.

SILVER, (ARGENTUM.)

Equivalent, 108. Symbol, Ag.

429. Silver is found native in small quantities. It also occurs mixed with several other metals, as copper, antimony, arsenic, and sometimes with gold, but is chiefly found in combination with sulphur, forming a sulphuret of silver.

This metal, when pure, admits of a luster only inferior to that of polished steel. Its specific gravity is 11, being about half that of platina. In malleability and ductility it excels all the other metals except gold and platina.

Silver is fused by the heat of a common furnace, and by a long continued and high degree of heat it may be volatilized, or turned into vapor. By slow cooling, this metal may be obtained in regular crystals. It is not oxidated by exposure to the combined action of heat and moisture, but is readily tarnished by sulphureous vapor. Sulphuric acid dissolves this metal, when assisted by heat, but its proper solvent is nitric acid, with which it readily combines, and when the solution is evaporated, forms nitrate of silver, a substance known under the name of *lunar caustic.*

Silver is precipitated from its solutions, by several of the other metals, in its metallic form. This happens when any other metal, having a stronger affinity for oxygen than silver, is placed in a solution of this metal.

What is the composition of sulphuret of mercury? What is the more common name for this compound? What is vermilion? In what state does silver occur? What are the substances with which it is chiefly found combined? What is its specific gravity? What is said of its malleability and ductility? How may silver be obtained in crystals? What vapor readily tarnishes silver? What is the proper solvent of this metal? What is the salt formed when silver is dissolved in nitric acid? How is lunar caustic formed? How may silver be precipitated in its metallic form?

If a quantity of nitrate of silver, or lunar caustic, be dissolved in water, and a slip of clean polished copper be dipped into it, the copper will be covered with a coat of silver.

430. Diana's silver tree.—Diana's silver tree is made by precipitating silver from its solution, by means of mercury. This interesting experiment may be performed in the following manner: Mix together six parts of a solution of nitrate of silver, and four parts of a solution of nitrate of mercury, both completely saturated. Add a small quantity of rain-water, and put the mixture into a glass decanter, containing six parts of amalgam, made of seven parts of mercury, by weight, and six parts of silver leaf. In the course of some hours there will appear small shining scales of metallic silver on the amalgam, which will increase, and shoot out in the form of a silver tree, producing a very beautiful appearance.

431. Silvering powder.—Silvering powder may be prepared in the following manner: Precipitate silver from its solution in nitric acid, by dropping into it some plates of clean copper. Take 20 grains of this powder, and mix with it two drams of cream of tartar, the same quantity of common salt, and half a dram of alum. These articles must be finely pulverized, and intimately mixed in a mortar. If a little of this powder be moistened, and rubbed on a clean surface of brass or copper, the silver will be precipitated, and the surface of the metal will be covered with it. In this way the silvering of candlesticks, or other articles, where it is worn off, may be replaced. The addition of the other articles to the precipitated silver, probably serves no other purpose than to keep the surface of the brass perfectly clean, and free from oxide, as the powder is rubbed on.

432. Silvering ivory.—Silver may also be precipitated on ivory, and then revived by the action of solar light. Into a dilute solution of nitrate of silver, immerse a slip of polished ivory, and let it remain until it acquires a yellow color, then place it in a tumbler of pure water, and expose it to the direct rays of the sun for a few hours, or until it turns black. If now it be gently rubbed, the surface will be changed into a bright metallic one, and the slip of ivory will, in appearance, be transmitted into one of silver. This change is caused by the deoxi-

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What is the process for forming Diana's silver tree? How may silvering powder be prepared? What is the use of the silvering powder? Of what use are the other ingredients in this powder besides the precipitated silver? What is the process for silvering ivory? How do you account for the return of the silver to its metallic state by being placed in the sun?

dizing power of the solar rays, in consequence of which the oxygen is separated from the silver, and the metal reduced to its former state.

A very useful solvent of silver is made by dissolving one part of niter with about eight parts of strong sulphuric acid. This solvent, when heated to about the temperature of boiling water, will dissolve silver, without acting on gold, copper, lead, or iron, and hence may be conveniently used to extract the silver from old plated goods, &c.

The combining number for silver is 108, it having been found that the oxide of this metal contains 108 silver, and 8 oxygen.

The sulphuret of silver is composed of 108 of the metal, and 16 sulphur.

GOLD, (AURUM.)

Equivalent, 98. Symbol, Au.

433. This well known precious metal is found only in the metallic state, either alone, or mixed with other metals; consequently, there is no such thing as an ore of gold. Gold is sometimes found disseminated in rocks, but always in its metallic state, and never mineralized by sulphur, oxygen, or any other substance. Its specific gravity is 19. It is the most malleable of all the metals, and in ductility is only excelled by platina.

434. MALLEABILITY OF GOLD.—The extent to which a given portion of this metal may be spread, and still continue a perfectly unbroken surface, is truly astonishing. A single grain of the best wrought gold leaf is found to cover fifty-six square inches, and it would take nearly 282,000 such leaves to make an inch in thickness. This, however, is not the utmost limit to which its tenuity may be extended, for the wire used by lace-makers is drawn from an ingot of silver, gilded with this leaf, and from the diameter of the ingot, compared with that of the wire, it has been found that the covering of gold on the latter is only a twelfth part of the thickness of gold leaf. Supposing the leaf, when first placed on the silver, to have been the 30 thousandth part of an inch in thickness, the covering on the wire would require 360,000 times its own thickness to make an

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What is the composition of a solvent for silver, which does not act upon other metals? What is the equivalent number for silver? In what state is gold always found? Are there any ores of gold? What is the specific gravity of gold? What illustrations are given of the malleability of gold? What is said of the thickness of this metal on the wire used by lace-makers?

inch; and still this covering is so entire that, even with a microscope, the silver is not to be seen.

Gold is the only metal which can be made so thin as to transmit the rays of light; and the rays so transmitted, instead of being of the same color with the metal, are green.

This metal, when pure, is not oxidated, or otherwise altered, by being kept in fusion, in the highest heat of a furnace, for any length of time. Sulphuric, nitric, or muriatic acid, do not, alone, produce the least action on gold; but when two parts of nitric and one of muriatic acid are mixed, forming *aqua regia*, the mixture dissolves this metal with facility. Put some nitric acid into another, and throw a little gold leaf into each. Not the least effect on either will be produced; but if the contents of one vessel be poured into the other, immediate action will ensue, and the metal will soon be dissolved.

The solution of gold is decomposed by many substances which have a stronger attraction for oxygen than this metal has, and by absorbing the oxygen, restores the gold to its metallic state.

435. HYDROGEN PRECIPITATES GOLD.—If a piece of ribbon, or other substance, be moistened with some dilute solution of gold, and exposed to the action of a current of hydrogen, the gold will be revived, and the ribbon, or other substance, will be covered with a film of gold. By means of a camel hair pencil, the solution may be applied to the ribbon in regular figures, and as the appearance of the ribbon is not changed by the application, until the hydrogen is thrown upon it, a striking experiment may be made in this way. The hydrogen must be applied while the ribbon is moist, and may be blown on, through a tube attached to a bladder containing it.

436. SULPHURIC ETHER PRECIPITATES GOLD.—Sulphuric ether precipitates gold, but instantly dissolves the precipitate, forming an ethereal solution of the metal. This solution is sometimes employed to gild lancets, scissors, and other instruments, in order to preserve them from rust. This is readily done by the following method. Into a given quantity, say an ounce, of the nitro-muriatic solution of gold, pour twice as much sulphuric ether; shake the vessel, and let it stand two or three minutes, and then pour into another vessel about one-third of

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What is said of the light seen through gold leaf? How is gold affected by continued fusion at the highest degrees of heat? What acids dissolve gold? How may the solutions of gold be decomposed? In what manner may figures of gold be made on ribbon? What are the directions for making an ethereal solution of gold?

the mixture. The acid does not mix with the ether, but settles to the bottom of the vessel, leaving the ether in possession of the gold on its surface; the portion decanted into the other vessel, therefore, is an ethereal solution of gold. Any perfectly clean and polished steel instrument will be covered with a coat of gold, if dipped for a moment into this solution. When taken from the ether, it should be instantly plunged into pure water, to wash off any particles of acid which may be retained in the solution. The instrument may afterward be burnished, when it will have all the appearance of the best gilding.

In this case the gold appears to be in its metallic state, and to be retained on the surface of the steel by the attraction of cohesion, while the ether evaporates.

PLATINUM.

Equivalent, 96. Symbol, Pt.

437. Platinum is a white metal, resembling silver in color, but a little darker. It is the heaviest of all known bodies, having a specific gravity of 22.

This metal comes chiefly from several parts of South America, where it is found in small grains, or scales, exceedingly heavy, and nearly the color of wrought-iron. In this state it is alloyed by several other metals, and requires to be purified before it is malleable. It was first discovered in 1741, but has not been applied to any considerable use until within the last fifty years. This metal has lately been discovered in considerable quantities in Russia, and is employed for the purposes of coin, for which it is well adapted.

Platina, like iron, may be welded, and like gold, suffers no change from the combined agencies of air and moisture, or by long continued heat. For many purposes, therefore, it is the most valuable of all the metals.

This metal is so difficult of fusion, as to undergo the greatest heat of a smith's forge without the least change; none of the acids act on it, except the nitro-muriatic, the solvent of gold.

438. How PURIFIED.—Platinum is purified and obtained in a malleable state by dissolving the grains in 8 times their weight of aqua regia, assisted by heat. The acid only dissolves the

In what manner may steel instruments be gilded with an ethereal solution of gold? What is the color of platinum? What is its specific gravity? Is there any known body of greater specific gravity than platina? In what countries is platina found? When was this metal discovered? In what respect does platina posses the property of iron? In what respect is this metal like gold? What is said of the action of heat, and of the acids, on platinum? How is this metal purified and rendered malleable?

platinum, leaving the iridium and osmium, the metals with which it is alloyed, in the form of a precipitate at the bottom of the vessel. The acid solution is then evaporated, and the metal precipitated by muriate of ammonia. The precipitate thus obtained, is heated in a crucible, lined with a mixture of clay and charcoal, to the utmost degree that can be attained in a blast furnace, when the ammonia and acid are driven off, and the fused metal falls to the bottom of the crucible. It is afterward several times heated, and hammered, when it becomes both ductile and malleable. In small quantities, this metal may be fused by the compound blow-pipe.

439. Alloys.—Platinum combines with many of the other metals by fusion, and forms alloys which possess various properties, some of which are useful.

Copper, when alloyed with from one-sixth to one twenty-fifth part of platina, becomes of a golden color, is much less readily oxidated than before, and receives a fine polish.

With iron, platina is said to form a compound highly esteemed by the Spaniards, for the purpose of making gun-barrels, which are stronger, and less apt to rust, than iron alone.

440. Uses.—From its infusibility, and the difficulty with which it is oxidated, this metal is highly useful in the arts, and particularly for making various chemical and philosophical instruments.

Retorts of platina are now employed instead of lead, for the distillation of sulphuric acid. Being acted on neither by heat, nor any single acid, such vessels will probably last even for centuries without repair. Their expense would, however, often be an objection to their use. In Mr. Tennant's great works for the manufacture of bleaching salt, at Glasgow, it is said there are nine platina retorts, which cost about 2,500 dollars each.

441. Aphlogistic lamp.—Platina is the slowest, or most imperfect conductor of heat among the metals, and from this quality, together with that of sustaining a high degree of heat without oxidation, it may be employed to construct the *aphlogistic*, or *flameless* lamp.

This curious lamp retains a coil of platina wire constantly at a white heat, without either flame or smoke. It may be constructed in the following manner:

The platina wire to be used for this purpose is about the thickness of card, or brass wire, No. 26. If larger, the

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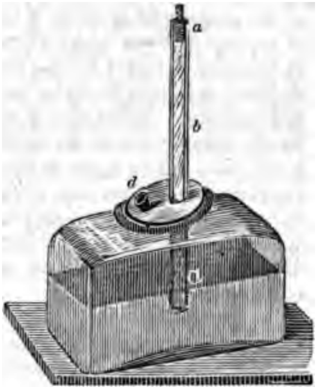
Does platinum form alloys with the other metals by fusion?

heat is carried off too fast, and the ignition ceases; and if much finer, it does not retain sufficient heat to keep up the evaporation of the alcohol, by the combustion of which the heat of the wire is maintained.

FIG. 101.



Aphlogistic Lamp.

Such a piece of wire, six or eight inches long, a piece of glass tube, and a low vial, are the chief materials for the construction of this lamp.

The coil, *a*, Fig. 101, is made by winding the wire round a piece of wood cut of the proper size and shape. The size is determined by that of the aperture of the tube, allowing for the diameter of the wire. Its shape is a little conical, or tapering upward. In winding the coil, it is best that the turns of the wire should come in contact, and afterward be gently extended, so as to come as nearly as possible to each other without touching. The diameter of the coil may be one-fourth, or one-sixth of an inch, and its length half an inch, containing twenty or thirty turns of the wire. *b* is a glass tube three or four inches long, containing the cotton wick by which the alcohol is carried up to the wire. The wick passes about half way through the coil. *c* is the body of the lamp which contains the alcohol. It is a low vial, or glass inkstand, capable of holding two or three ounces. The glass tube passes through a cork, and dips into the fluid. *d* is a small tube through which the alcohol is poured. This must be stopped to prevent evaporation.

When the lamp is thus prepared and filled with alcohol, the fluid is set on fire by holding the platina wire in the flame of a candle, and after a few minutes, or when the coil becomes red hot, the flame is blown out, and if every thing is properly adjusted, the wire will remain red hot as long as the vial contains alcohol.

What alloys of platina are mentioned as being useful? For what useful purposes has the pure metal been employed? Is platina a good or bad conductor of heat? What is the aphlogistic or flameless lamp? Explain Fig 101, and describe the construction of the flameless lamp. With what fluid is the lamp filled?

442. EXPLANATION.—The following appears to be the causes of the permanent ignition of the wire. Alcohol, when in a state of vapor, combines with oxygen with facility. The temperature of the wire is raised by the flame of the candle to about 1000 degrees, the point at which alcohol combines with oxygen, or is combustible. When this is once effected, the caloric extricated by the combustion of the alcohol is sufficient to keep the coil at a red heat, which again is the temperature at which alcohol is combustible, so that one portion of alcohol, by the absorption of oxygen, and the consequent evolution of heat, prepares the wire to effect the combustion of another portion, and as the alcohol rises in a constant stream of vapor, so the ignition is constant.

Before the invention of friction matches, this lamp was highly convenient, for by touching a match to the coil, and then to the wick of a candle, a light was immediately obtained.

Platinum combines with oxygen in two proportions, forming the

Protoxide, 1 eq. plat. 96+1 eq. oxy. 8.
Peroxide, 1 " " 96+2 " " 16.

PALLADIUM AND RHODIUM.

443. These two metals were discovered by Dr. Wollaston, in 1803, in the ore of platinum. When this ore is digested in nitro-hydrochloric acid, the platinum, together with the palladium, rhodium, iron, copper, and lead, is dissolved; while a black powder is left, consisting of osmium and iridium, mixed in general with a considerable quantity of titanite of iron, and insoluble matter.

PALLADIUM.

Equivalent, 54. Symbol, Pd.

444. This is one of the rare metals, and is obtained in its pure state with difficulty. It resembles platina in color and luster. It is malleable and ductile, and is much harder than platinum. Its specific gravity is about 11.8. Its fusibility is intermediate between gold and platinum, and when intensely heated by the oxy-hydrogen blow-pipe, is dissipated in sparks.

How is it lighted? Explain the principles which cause the permanent ignition of the platina wire. What is the use of the aphlogistic lamp? What is the equivalent number for platinum? What are the names of the oxides of this metal, and what the proportions of their elements? Where were the metals palladium, rhodium, iridium, and osmium, first discovered? What is the combining number for palladium?

It is oxidized and dissolved by nitric acid, but its proper solvent is nitro-hydrochloric acid. Its protoxide forms beautiful red salts, from which metallic palladium is precipitated by the sulphate of proxide of iron. Its compounds are not numerous, though it combines with oxygen in two proportions, forming a *protoxide* and a *binoxide;* with chlorine, forming the *protochloride* and the *bichloride*, and with sulphur, forming the *protosulphuret.*

RHODIUM.

Equivalent, 52. Symbol, R.

445. On immersing a plate of clean iron into the solution from which palladium and most of the platinum have been precipitated, the rhodium, with small quantities of lead, copper, and platinum, is thrown down in the metallic state. The rhodium is afterward separated by means of several processes not necessary to detail. It is procured in the form of a black powder, which being fused by the strongest heat of a wind furnace, produces the metal in question. Its color is white, with a metallic luster, and a specific gravity of about 11. It is extremely hard, scratching hardened steel, and is not attacked by any of the acids in its pure state. Chemists are acquainted with two oxides of rhodium, and several salts, which are either red or yellow. It is only soluble in acids when alloyed with other metals.

USE.—It is employed for the points of metallic pens, for which, owing to its extreme hardness and insolubility in acids, it is admirably adapted. The gold pens of the present day owe their lasting property to this metal.

OSMIUM AND IRIDIUM.

446. These metals owe their discovery to Mr. Tennant, in 1803. The black powder, mentioned at the beginning of this article, as containing these metals, is the source whence they were obtained. The manipulations resulting in obtaining them in the pure state, are long and difficult.

What is the specific gravity of rhodium? What is the color, and what are the properties of rhodium? From what circumstance is the name of this metal derived? What is the equivalent number of rhodium? How are iridium and osmium obtained? What is the specific gravity of iridium? What is said of its fusibility, and solution in acids?

OSMIUM.

Equivalent, 100. Symbol, Os.

447. This metal appears at first in the form of a porous mass, which acquires metallic luster by friction. It takes fire when heated in the open air, and is readily dissolved by nitric acid. In its densest state its specific gravity is 10. It combines with oxygen and the acids, forming many compounds, which our limits do not allow us to describe.

Osmic acid.—This is the product of the oxidation of osmium by acids, or by combustion. It is in the form of elongated, transparent crystals, having an exceedingly acrid vapor, exciting cough, producing tears, and a copious flow of saliva. Its odor is disagreeable and pungent, somewhat like that of chlorine, and this property suggested its name from a Greek word signifying *odor*. Neither the metal, nor its compounds, have been applied to any use.

IRIDIUM.

Equivalent, 99. Symbol, Ir.

448. This is a very brittle metal, and, without care, will fall into powder in attempting to burnish it. When polished, it resembles platinum in color and luster. Of all known metals it is the most infusible. Berzelius never succeeded in melting it, but Mr. Children, with his immense galvanic battery, fused it into a brilliant metallic globule of a white color, having a specific gravity of nearly 19, being, in respect to this property, next to platinum.

Iridium combines with oxygen and chloric acid, forming oxides and chlorides.

CLASS II.

449. *Metals, the oxides of which are not reducible to the metallic state by heat alone.*

Order 1.—*Metals which decompose water at common temperatures.* These are

- Potassium,
- Sodium,
- Lithium,
- Barium,
- Strontium,
- Calcium.

What are the properties of osmium? How is osmium obtained in its pure state? What is the definition of Class II? What is the definition of Order 1st, of this class? What are the names of the metals belonging to this order?

These metals attract oxygen with the most intense degree of force. They absorb it from the atmosphere, and even decompose water, by combining with its oxygen, at common temperatures. Such is the force by which they hold this principle, that their oxides had resisted all attempts to decompose them, until the discovery of galvanism placed in the hands of men a more powerful decomposing agent than was before known. By means of the most intense electrical repulsion, the alkalies, before considered as simple bodies, were shown to be the oxides of metals. After the secret of their composition was known, chemists devised other and less expensive means of effecting their decompositions, so that at the present time, sodium and potassium, at first the most expensive of all substances, are within the means of any one.

POTASSIUM, (KALIUM.)

Equivalent, 40. Symbol, K.

450. DECOMPOSITION OF POTASH.—If a small piece of pure potash, slightly moistened, be put between two plates of platinum connected with the poles of a galvanic battery of 200 double plates, the alkali will soon be fused and decomposed. Oxygen will separate at the positive poles, and small metallic globules, like quicksilver, will appear at the negative pole. In this manner, Sir H. Davy first determined the composition of potash, and separated its elements. Potash, therefore, is a compound consisting of a metal called *potassium*, united to oxygen.

By this process the metal can be obtained only in minute quantities; but chemists, now understanding that to obtain potassium in any quantity, only required that the oxygen should be separated from the potash, soon found more ready means of performing the experiment.

451. DECOMPOSITION BY CHARCOAL.—In the former editions of this work, Thenard's process for the making of potassium was given, illustrated by a diagram. In this process, the decomposition was effected by means of a heated gun-barrel, containing iron turnings, the oxygen of the potash being absorbed by the iron at a high heat. It has since been discovered that the decomposition can be performed more readily by charcoal

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What is said of the intense degree of force with which these metals att-
By what decomposing agent were the alkalies shown to be the oxid
What is the process by which Sir H. Davy decomposed potash?

than by iron, and hençe, at present, this forms the bases of the process for potassium, now always followed. The process, however, requires more apparatus, and more chemical experience than usually pertains to the students of this humble treatise, and we have, therefore, omitted the description and apparatus for this purpose in this edition, referring the inquirer for a complete account of the process, with explanatory diagrams, to the last edition of Graham's Chemistry, Part I., page 370. There he will find an extended account of the most recent methods of obtaining this most interesting and curious metal.

452. Potassium is solid at ordinary temperatures, but becomes fluid at 150 degrees, and then appears like mercury. It is perfectly opaque, and a good conductor of electricity and caloric. At the temperature of 50 degrees, it is soft like wax, and yields to the pressure of the fingers. In this state it resembles an amalgam of mercury and tin. Its specific gravity is 0.865, water being 1.000.

The most prominent chemical property of this metal is its extreme avidity for oxygen. When exposed to the air it oxidizes rapidly, and when thrown on water it decomposes that fluid, by absorbing its oxygen with such rapidity as to set itself on fire, and burns with a white flame, and great evolution of heat, while swimming on its surface.

POTASSIUM AND OXYGEN.

PROTOXIDE OF POTASSIUM.

Equivalent, 48. Symbol, KO.

1 eq. Potassium, 40+1 eq. Oxygen, 8.

POTASH.

453. Potassium combines with oxygen in two proportions, forming the protoxide and peroxide of potassium. The first, which is common potash, is formed whenever potassium is put into water, or exposed to dry air, or oxygen gas.

The proportion of oxygen which this metal absorbs, to convert it into potash, is readily ascertained by the volume of hydrogen liberated when it acts on water. For, when potassium

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What is the principle on which the decomposition of the potash is effected by means of iron turnings and heat? What is the appearance of potassium? Is it a conductor of caloric and electricity? At what temperature does it become fluid, and at what temperature is it solid? What is the specific gravity of this metal? What phenomena are produced when potassium is thrown on water? In how many proportions does potassium combine with oxygen? What common substance is formed when potassium is exposed to the air? When potassium is plunged under water, how is it ascertained what quantity of oxygen it absorbs?

is plunged at once under that fluid, it is oxidized without the evolution of light or heat, and it is found that each grain of the metal so placed, separates 106 cubic inches of hydrogen gas. Now, by knowing previously what are the relative volumes and weight of hydrogen and oxygen composing water, it is easy to calculate the exact quantity of oxygen absorbed by the above data.

Thus, Sir H. Davy found that 40 grains of this metal decomposes precisely 90 grains of water. Now, as 9 grains of water is composed of 1 grain of hydrogen, and 8 oxygen, so 40 parts of potassium combines with 8 parts of oxygen, to form oxide of potassium, or potash. Potash is therefore composed of

Potassium, 1 eq. 40 + Oxygen, 1 eq. 8 = 48.
48 combining number for potash.

When potassium is allowed to absorb oxygen in the open air, or when plunged under water, it combines with only one proportion of oxygen, as above stated. But when this metal burns in the open air, or in oxygen gas, it is converted into an orange colored substance, which is the peroxide of potassium. This is composed of

Potassium, 1 eq. 40 + 3 eq. Oxygen, 24 = 64.

454 The potash of commerce is obtained from the lye of wood ashes, boiled down in pots, and hence the name *potash*. It is chiefly used in the manufacture of soap and glass. For the former purpose, the lye itself is often employed, and is better than the solid potash, dissolved in water, since the potash soon absorbs carbonic acid, and then its quality for soap-making is in a great measure destroyed. From this circumstance it is, that soap-makers mix with their lye a quantity of newly burned quicklime, which renders the solution of potash caustic, by absorbing from it the carbonic acid, with which it has combined.

Soft soap only can be made from potash, while hard soap is made from soda.

Common green glass is made by fusing sand and wood ashes

Suppose 40 grains of potassium decompose 9 grains of water, how does it appear in what proportion potassium and oxygen combine ? What is the equivalent number for potash ? When potassium is burned in the open air, or in oxygen gas, what proportion of oxygen does it absorb ? What is the oxide called which is so formed ? How is the potash of commerce procured ? In what manufactures is the article chiefly employed ? What is the use of quicklime in soap-making ? How do the soaps made from potash and soda differ ? What are the materials for making green glass ?

together, by means of an intense heat, produced by the combustion of dried wood, in a blast furnace. Flint glass, which is perfectly white and transparent, is made by fusing together a quantity of potash and white sand, or ground quartz, to which are added a proportion of lead, and a little manganese.

Salt of tartar, salt of wormwood, pearl-ash, and carbonate of potash, are only different names for the same article, some of which are more pure than others.

SODIUM, (NATRON.)

Equivalent, 24. Symbol, Na.

455. By the same process which showed potash to be a compound body, soda was also found to be of the same nature. Although first procured by means of galvanism, it may be obtained by precisely the same method as that described for the production of potassium, only placing soda in the gun-barrel, instead of potash.

Sodium has a strong metallic luster, similar to that of silver. It is a little less fusible than potassium, not becoming perfectly fluid until it has acquired the temperature of nearly 200 degrees. Its specific gravity is somewhat greater than that of potassium, being 0.972. When thrown on water it produces a violent effervescence, but does not inflame like potassium. The water is decomposed by its action, hydrogen escapes, and there remains a solution of soda in the water. Like potassium, it must be preserved in a vial, covered by *naphtha*—a substance which contains no oxygen.

SODIUM AND OXYGEN.

PROTOXIDE OF SODIUM.

Equivalent, 32. Symbol, NaO.

1 eq. Soda, 24 + 1 eq. Oxygen, 8.

SODA.

456. When the metallic base of soda is burned in dry atmospheric air, protoxide of sodium, or soda, is formed. The same

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What are the materials for making flint glass? What other names are applied to potash? What is the process of decomposing soda, and obtaining the metal sodium? What is the appearance of sodium? In what respects does this metal differ from potassium? What is the effect when sodium is thrown upon water? How is the metal preserved? What compound is formed when sodium is burned in atmospheric air, or thrown into water? What is the composition of protoxide of sodium, or soda?

compound is formed when sodium is thrown into water, and the composition may therefore be determined in the manner already described for potassium. From such an experiment it has been found that soda is composed of

Sodium,	1 equivalent,	24
Oxygen,	1 "	8
		32 equivalent of soda.

The peroxide of soda is composed of the same equivalent of sodium, with two equivalents of oxygen. Sodium, 24, oxygen, 16—40.

Soda is readily distinguished from other alkalies by the following characters. With muriatic acid it forms the common table salt, with the taste of which every one is familiar. With sulphuric acid it forms Glauber's salt, or sulphate of soda. All the salts of soda are soluble in water, and are not precipitated by any other substances.

SODIUM AND CHLORINE.

CHLORIDE OF SODIUM.

Equivalent, 60. Symbol, NaCl.

1 eq. Sodium, 24 + 1 eq. Chlorine, 36.

COMMON SALT.

457. When sodium is exposed to chlorine, or is heated in muriatic acid gas, the salt is formed, well known under the name of muriate of soda, or common salt. This is an abundant product of nature, and exists ready formed in Spain, England, Poland, and other countries, in large quantities. In these countries it is dug out of the earth, and is known by the name of *rock salt.* Sea water and certain springs also contain this salt in solution.

When common salt is dissolved in water, and the solution is evaporated rapidly, it crystallizes in the form of hollow four-sided pyramids; but if allowed to evaporate spontaneously, it occurs in regular cubes. Thus, the crystals show in what manner the salt has been manufactured. In England, vast quanti-

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What is the equivalent number for soda? How is soda distinguished from th other alkalies? What is chloride of sodium? What the sources of common s When a solution of common salt is evaporated rapidly, what is the form of its c tals? When evaporated slowly, in what form are the crystals? Where are the mines of England? What impurities exist in the Cheshire rock salt?

ties of salt are annually raised from the mines, chiefly of Cheshire, and purified for sale. The impurities consist chiefly of clay and oxide of iron, besides which, it contains various proportions of sulphate of magnesia, or Epsom salt, sulphate of lime, and muriate of lime. It is purified by being dissolved in sea-water, and subsequently evaporated. Formerly, all the English salt was evaporated by artificial heat, the brine being boiled until it was ready to shoot into crystals. Its crystals were, therefore, always in the form of hollow pyramids. But it has been supposed, by victualers and others, that this salt is far less efficacious, as a preserver of animal food, than that prepared by the spontaneous evaporation of sea-water in hot climates. Hence, salt from the West Indies, which is crystallized in solid cubes, has been preferred for curing provisions for long voyages, or for summer use. In this country, although immense quantities of common salt are manufactured, by the evaporation of water from salt springs and from the sea, and a sufficient supply for our consumption might be made, yet we annually import large quantities from the West Indies, there having been, until lately, an opinion that no other kind of salt would preserve animal substances through the hot season.

458. Dr. Henry, for the purpose of ascertaining the difference between English salt, crystallized by heat, and that from the West Indies, crystallized by spontaneous evaporation, analyzed many specimens of each. The result showed the presence of sulphate of magnesia and sulphate of lime in both, but the difference in the quantity of muriate of soda, in several specimens of each kind, was so trifling, as to make no possible difference in respect to their preserving qualities. It is presumed, therefore, that the prejudices in favor of foreign salt ought to be discarded as imaginary, and that equal weights of fine or coarse salt, whether made by artificial, or spontaneous evaporation, are equally efficacious for all purposes.

Common salt contains no water of crystallization, but decrepitates remarkably when heated, owing to the conversion of the water into steam, which is mechanically confined within its crystals. Its solubility is not, like most other salts, increased by

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How is this salt purified? Why were the crystals of this salt always in the form of hollow pyramids? What salt was formerly supposed best for the preservation of animal substances? What is said of the real difference between salt made by rapid or slow evaporation? Does common salt contain any water of crystallization? Why does common salt decrepitate, or fly in pieces, when thrown upon a fire? Is the solubility of this salt, increased by heat? What quantity of water does it require for solution?

heat, and it requires two and a half times its weight of water for solution, whether hot or cold.

LITHIUM.

Equivalent. 6.43. Symbol. L.

459. *Lithia* is an alkaline substance, discovered by M. Arfwedson, a Swedish chemist, in 1818. It exists in the minerals called *spodumene*, and *lepidolite*, and also in some varieties of mica.

This alkali is distinguished from potash and soda, by its power of neutralizing larger quantities of the different acids, and by its action on platinum, when melted on that metal.

In respect to its metallic base, called lithium, Sir H. Davy succeeded, by means of galvanism, in obtaining a white metal from lithia, similar in appearance to sodium, but it was oxidized so rapidly, and reconverted into the alkali, that it could not be collected.

Lithium combines with several acids, forming salts of various kinds, as the *carbonate of lithia, sulphate of lithia*, &c. It also unites with sulphur, forming the sulphide of lithium.

Lithia has been procured only in very small quantities, and has never been applied to any useful purpose.

BARIUM.

Equivalent, 69. Symbol, Ba.

460. There is a substance called *sulphate of barytes*, which is found abundantly in nature. By the decomposition of this substance, an alkaline earth is obtained, called *baryta*, or *barytes*. When barytes, in the form of paste mixed with water, is exposed, in contact with mercury, to the action of a powerful galvanic battery, its decomposition is effected, and the metal *barium*, its base, amalgamates with the mercury. The amalgam being exposed to heat, the mercury is driven off, and pure barium remains.

The metal thus obtained, is of a dark gray color, with a luster inferior to cast-iron. It fuses at a heat below redness, and at a red heat is converted into vapor, which acts violently upon

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What is lithia? In what minerals is this alkali found? How is lithia distinguished from potash and soda? What is known concerning the metallic base of
What are the equivalent numbers of lithium and lithia? How is bary
By what process is barium separated from baryta? What is the col
At what temperature is barium fusible? What is the specific gravity

glass. The specific gravity of barium is four or five times that of water. When exposed to the air it falls into a white powder, which is found to be an oxide of barium, or barytes. When heated in oxygen, it burns with a deep red light, and when thrown into the water, the fluid is decomposed, hydrogen being extricated.

BARIUM AND OXYGEN.

PROTOXIDE OF BARIUM.

Equivalent, 77. Symbol, BaO.

1 eq. Barium, 69+1 eq. Oxygen, 8.

BARYTES.

461. When the metal barium is exposed to the air it falls into a powder, which was formerly called *pure barytes*, or baryta, but which Sir H. Davy has proved by the above-stated experiment, to consist of a metal and oxygen. This substance is, therefore, called *oxide of barium.*

Oxide of barium may also be obtained by a different process from that above described, viz., by exposing the carbonate of baryta to an intense heat, mixed with charcoal.

The carbonate of barytes is found native in small quantities, but may be obtained from the sulphate of barytes by a simple process. Mix sulphate of barytes in fine powder, with three times its weight of carbonate of potash, (pearl-ash,) and a proper quantity of water. Let the mixture boil for an hour, now and then breaking the lumps into which it is apt to run, with a pestle. By this means the two salts will decompose each other, and there will be formed carbonate of barytes, and sulphate of potash. The carbonate may now be exposed to a high heat, or it may be dissolved in nitric acid, and thus decomposed, which is effected by a moderate heat, when protoxide of barium, or barytes, will be obtained. This substance is of a white color, has a sharp caustic taste; changes vegetable blue colors to green; neutralizes acids, with which it forms salts, and is a strong poison. When water is thrown on it, it falls into fine powder, like quicklime, but with a greater evolution of heat.

When barium is exposed to the air, what compound is formed? When thrown into water, what effects are produced? By what process may barium be obtained without the agency of galvanism? How may carbonate of barytes be extracted from the sulphate? What are the properties of barytes, or protoxide of barium? What is the composition of barytes? In what quantity of water is barytes soluble? Why is barytes a test for carbonic acid?

Barytes is composed of

1 equivalent of barium, ...	69
1 " " oxygen, ...	8
The equivalent combining number for barytes,	77

Barytes is soluble in about twenty parts of water, at common temperatures, and this solution forms a delicate test for the presence of carbonic acid. The carbonate of barytes being insoluble in water, a white cloud is instantly formed by the union.

STRONTIUM.

Equivalent, 44. Symbol, Sr.

462. The sulphate and carbonate of strontian, or strontia, are native salts. They consist of pure strontian, combined with sulphuric and carbonic acids. From the sulphate, the carbonate may be procured by precisely the same means as already described for barytes, and the pure oxide may also be obtained, and the metal strontium separated from it, by the same process as that described for barytes.

Strontia resembles baryta in most respects. It slakes in water, causing an intense heat, and possesses distinct alkaline properties.

The metal strontium is similar to barium in appearance, and when exposed to the air quickly attracts oxygen, and is converted into strontia. Perhaps the principal difference between these two substances, which has been detected, is their different combining proportions with oxygen, and the inertness of the oxide of strontium on animals.

The protoxide of strontium consists of

Strontium,	1 equivalent,	44
Oxygen,	1 "	8
		52

The oxides of barium, as already stated, are strong poisons, but those of strontium are inert.

How is the carbonate of strontian produced from the sulphate? How is the pure earth strontia obtained from the carbonate? By what process is the metal strontium separated from strontia? What is the appearance of this metal? What is the composition of strontia, or the protoxide of strontium? What is the combining number of strontia? What is the difference between strontia and baryta?

CALCIUM.

Equivalent, 20. Symbol, Ca.

463. When carbonate of lime, or white marble, is exposed to a red heat, the carbonic acid is expelled, and there remains a white caustic substance, well known under the name of *quicklime.* When this substance is exposed to the action of galvanism, in the same manner as already described for the decomposition of barytes, *calcium*, the metallic base of lime, is separated. This metal is of a whiter color than barium, and has a luster like silver. When exposed to the air, it absorbs oxygen, and is converted into quicklime; and when thrown into water, the fluid is decomposed, its oxygen being absorbed, while hydrogen is given off, and a solution of lime remains.

464. Artificial marble.—To Mrs. Marshall, of Edinburgh, we are indebted for the following singular, and perhaps important suggestions and experiments, as detailed in Chambers' Journal. In about 1840, Mrs. Marshall was struck with the singular idea, that the animal and vegetable remains so universally found in certain strata of the earth, might, by a chemical or electric influence exerted upon the disintegrated particles of these rocks, have been the cause of their aggregation. The result of numerous experiments undertaken by herself, has, she states, satisfactorily demonstrated, that if the constituents of any mineral body of which lime forms a part, be mixed in their true proportions, (the lime used being free from carbon in any form,) and these mixed with animal and vegetable remains, under circumstances of due moisture and heat, aggregation of their particles will take place, at periods varying with the substances under experiment, from a few minutes to hours, weeks, and months. These artificial aggregations, allowing for shortness of time and amount of superincumbent pressure in the natural phenomena, come so undeniably near, in appearance and qualities to the products of nature, as to throw a totally new and interesting light on some of her hitherto most mysterious operations.

Mrs. Marshall's experiments show, that if a mass, in imitation of a native mineral aggregate, be prepared, and one portion left at rest, while another portion is agitated or disturbed, the first will harden in a few hours or days, into a substance not to be distinguished by the eye from the natural stone, and capable of

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What is quicklime? How may quicklime be decomposed, and calcium, its metallic base, be separated? What is the appearance of calcium? How is calcium converted into quicklime? What effect is produced when calcium is thrown into water? Give an account of Mrs. Marshall's method of making artificial marble.

resisting water and weather, while the other portion will take as many weeks to harden, and will then present a mass which will fall in pieces by exposure to either.

These experiments are, to all appearance, worthy of general consideration and further trial, for if durable stone can be made from the useless chips and refuse of marble quarries, the result may be of vast benefit to the world.

CALCIUM AND OXYGEN.

OXIDE OF CALCIUM.

Equivalent, 28. Symbol, CaO.

1 eq. Calcium, 20+1 eq. Oxygen, 8.

QUICKLIME.

465. From the quantity of hydrogen evolved by the action of calcium on water, it has been determined that lime is composed of

Calcium,	1 equivalent,	20
Oxygen,	1 "	8
Making the equivalent for lime,		28

Carbonate of lime exists in great abundance as a natural product, under the names of *limestone*, *marble*, and *chalk*. Quicklime, the pure earth, is obtained by exposing the carbonate to heat, and is a substance of great importance in the arts, and particularly in building. Mortar is composed of this substance, combined with water, and mixed with a proportion of sand.

Quicklime absorbs water with remarkable avidity, and at the same time a high degree of heat is produced. This process is called *slaking*, and the heat is caused by the condensation of the water into a solid state, in consequence of which caloric is evolved. The lime will remain perfectly dry after having absorbed one-third of its weight of water, which therefore forms a part of the slaked lime, or hydrate of lime.

Hydrate of lime is composed of

28 parts,	or 1 proportion of lime.
9 parts,	or 1 " " water.
37	is therefore its combining number.

How is the combining proportion of oxygen with calcium determined? What is the composition of lime, or oxide of calcium?

466. Lime is very sparingly soluble in water, and it is a singular fact, that it is more soluble in cold, than in hot water. Thus, Mr. Dalton found that one grain of lime, at the temperature of 212 degrees, required 1270 grains of water for its solution, while at the temperature of 60 degrees, the same quantity was dissolved in 778 grains of water. By other experiments, it has been found that water, at the freezing point, will take up just twice the quantity of lime that it will at the boiling point. Consequently, on heating lime water, which has been prepared in the cold, a deposition of the lime will ensue. Lime water, therefore, when used for medicinal purposes, should be prepared in cold, instead of hot water, as commonly directed, and should also be kept in a cool place. It should likewise be closely stopped from the air, for, as the lime has a strong attraction for carbonic acid, of which the atmosphere always contains a small portion, if left open, it is soon converted into carbonate of lime, as shown by the production of a thin pellicle on its surface.

Lime water is a delicate test for the presence of carbonic acid, with which it forms a white insoluble compound, the carbonate of lime. The air from the lungs contains a small quantity of carbonic acid, and hence, on blowing into a vessel of clear lime water, it instantly becomes cloudy, or turbid.

LIME AND CHLORINE.

CHLORIDE OF LIME.

Equivalent, 92. Symbol, Ca_2Cl.

2 eq. Lime, 56 + 1 eq. Chlorine, 36.

BLEACHING POWDER.

467. The gas called chlorine, as already shown, possesses strong bleaching or whitening powers; but as it would be inconvenient to manufacture this gas at every place where it is wanted, and as its application is more convenient when combined with some other substance, it is found that in practice,

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What is the equivalent number for lime? What causes the heat, when water is thrown on quicklime? What is the scientific name for slaked quicklime? What is the composition of hydrate of lime? What singular fact is mentioned concerning the solubility of lime in cold and hot water? How much more lime will water dissolve at the freezing than at the boiling point? Had lime water, for medicinal purposes, ought to be made with hot or cold water? Why? Why should lime water be closely stopped from the air? Why does lime water become cloudy when air from the lungs is blown into it? What is the chemical name for bleaching powder? Does the bleaching property exist in the lime or in the chlorine? What are the advantages of combining the chlorine with the lime for this purpose?

these purposes are best answered by first combining it with lime. The manufacture of bleaching powder is a business of great importance, and is carried on in large establishments prepared for the purpose.

468. Retorts for chlorine.—The retorts, in which the gas is extricated, are made of lead or platina. If of lead, they must be of new metal and cast, for the gas acts on tin, a part of the composition of solder, and since old lead generally contains a portion of this metal, owing to its having been soldered, it is soon destroyed. These retorts are placed in iron vessels of water, to which the heat is applied. In large manufactories, each retort is capable of containing 10 cwt. of common salt, ground with from 10 to 14 cwt. of black oxide of manganese, in proportion as the latter contains more or less oxygen. This being introduced, there is added from 16 to 18 cwt. of sulphuric acid, of the specific gravity of 1650. The lime, recently slaked, is contained in trays or shallow boxes of wood, placed in a large chamber, built of granite, or siliceous sandstone, or lined on the inside with lead. This chamber has two windows of glass, opposite to each other, through which the workmen are enabled to see how the process goes on. Every part of this chamber is made air-tight, the door being secured by fat lute, and strips of cloth.

In order to get rid of the remaining gas, after the absorption of the lime is completed, there are three trap-doors, one in the roof, and two in the floor or sides of the chamber. These are opened by means of ropes and pullies, so that the workmen may avoid the vapor that passes out.

469. Process for chlorine.—The lime being placed in the boxes, the gas is let into the chamber from the retorts, under which a fire is afterward kindled, in order to hasten the process, and obtain more chlorine. The gas, being heavier than air, is let in at the upper part of the room, and gradually descends, while the air in part mixes with it, and in part rises above it.

The lime absorbs the chlorine with great avidity, its condensation causing the evolution of a large quantity of caloric; the latter circumstance is, however, to be avoided, as too high a heat partly decomposes the chloride of lime, by expelling the

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Why must new lead be used for retorts in making chlorine? Describe the chamber in which the lime, for making the chloride of lime, is placed. What contains the lime when placed in the chamber? Into what part of the room is the chlorine admitted? Why must the chlorine be admitted slowly? If the heat rises too high why is there a muriate, instead of a chloride of lime formed?

oxygen, and thus forming a chloride of calcium, instead of a chloride of lime. The gas is, therefore, admitted slowly, in order to avoid this consequence.

The process continues four days, before the absorption is considered sufficient to make the best bleaching powder, for its quality depends entirely on the quantity of chlorine which the lime contains.

470. In some manufactories, the lime is stirred by means of rakes, with long handles, passing through the sides of the room, the passages being made close by means of milk of lime, or lime moistened, so as to be about the consistence of cream, and contained in boxes through which the handle passes. In others, the traps above described, are opened at the end of two days from the beginning of the process, and when the gas has subsided, the workmen enter and rake over the lime, so as to present a new surface to the action of the gas. The doors and traps are then closed, and the gas admitted for two days more, at the end of which time the process is finished, and the doors are again opened, and the chloride of lime removed, and put into close casks for use.

In general, according to Mr. Gray, a tun and a half of good bleaching powder is considered the average product of each tun of the salt employed.

471. It is said that the principal difficulty in the manufacture of this article, is the production of chloride of calcium, by decomposition, instead of the chloride of lime. To understand the cause of this difficulty, it must be remembered, that calcium and chlorine have a stronger affinity for each other than calcium and oxygen. Lime is composed of calcium and oxygen; and chloride of lime is therefore composed of oxygen, calcium, and chlorine. Now these three elements being present, there is formed a chloride of calcium, in consequence of the cause just stated; and in proportion as this is formed, the bleaching property of the salt is destroyed, this property being possessed only by the chloride of lime. The same effect is produced when the temperature is raised too high during the manufacture of this compound, for then the oxygen of the lime or base

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How long a time is required for making the best bleaching powder? In what manner is the lime stirred, in order to hasten its absorption of the chlorine? What proportion does the bleaching powder formed, bear to the quantity of salt employed? What is said to be the principal difficulty in the manufacture of bleaching powder? What is the difference in composition between muriate of lime and chloride of lime? Explain the chemical changes which take place when chloride of lime is decomposed by heat, and converted into muriate of lime. In what manner is chloride of lime decomposed, when it is exposed to the atmosphere?

is expelled, and the calcium and chlorine form chloride of calcium. The only mode of avoiding this difficulty appears to consist in admitting the chlorine slowly, as already stated.

This salt is also subject to decomposition from other causes. When mixed with water, and exposed to the action of the atmosphere, carbonic acid unites with the lime, while the chlorine is expelled, and thus a carbonate instead of a chloride remains, or by decomposition of the water, a muriate of lime is formed, which is also without bleaching properties.

472. As the goodness of bleaching powder depends entirely on the quantity of chlorine it contains, it is a matter of great consequence to the purchaser to ascertain its quality in this respect, by actual experiment. According to the experiments of Dr. Ure, lime, under a slight pressure, is capable of condensing nearly its own weight of chlorine; but according to the same author, the bleaching powder of commerce always contains a considerable proportion of the nitrate of lime, while the chloride itself often does not contain more than one-half or one-third the quantity of chlorine which the lime is capable of absorbing. Hence the consumers of this article are often cheated out of one-half or two-thirds of the price they pay for it, besides the delay and vexation incident upon the failure of the process in which it is used. The manufacturers of paper and cotton goods are often sensible of this fact, by experience.

It appears, on experiment, that when bleaching powder is kept for a considerable time, even in a properly secured vessel, such as glass bottles well corked, that it still slowly undergoes the same change, which is immediately effected by heat, as described above. This seems to be in consequence of the superior affinity of chlorine for the calcium, or the metallic bases of the lime, by which the oxygen is slowly disengaged, and a chloride of calcium, or muriate of lime, is formed, and thus the bleaching powder is in process of time entirely destroyed.

The principal expense of manufacturing chloride of lime, being that of the chlorine itself, and there being no method of ascertaining its quantity, except by experiment, the purchaser generally has to depend chiefly on the honesty of the manufacturer, for the goodness of the article, even when recently made. But as there are several causes of decomposition, even when it

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On what does the bleaching property of the chloride depend? What quantity of chlorine is lime capable of absorbing? According to Dr. Ure, what does the bleaching powder of commerce contain besides the chloride of lime? What kind of decomposition does bleaching powder slowly undergo when confined in close vessels?

is honestly and carefully made, the buyer is still liable to be deceived, unless he makes his experiment before the purchase.

Under such circumstances, the English chemists have devised several simple methods of testing the quality of bleaching powder, in order that the buyer might judge of its goodness without actual trial at home.

473. TEST FOR CHLORIDE OF LIME.—One of these methods is, to expose the salt to a sufficient degree of heat to expel the oxygen from the lime, and by measuring its quantity, to judge of the quantity of the chloride of lime. The quantity of oxygen thus expelled, indicates the quality of the bleaching powder, so far only as regards the quantity of muriate of lime with which it is mixed; for, as above stated, the base of the chloride contains oxygen, while the muriate contains none. But in addition to the imperfections of this method in not indicating the actual quantity of chlorine present, there is much difficulty in ascertaining the quantity of oxygen by it, since various proportions of chlorine might also be disengaged by the heat, along with the oxygen. This method can not, therefore, be readily or generally employed.

It has also been proposed to analyze the powder by nitrate of silver. But this test only indicates the quantity of muriate of lime, by forming with the muriatic acid an insoluble chloride of silver. This test is therefore useless.

Several other methods have been tried, and among them, that of destroying the color of a certain quantity of indigo has been most employed.

A known quantity of indigo being in solution, a certain number of grains of the powder is added, and the strength of the latter ascertained by the amount of coloring matter destroyed, or by the number of grains required to discharge, entirely, the color of a certain quantity of indigo.

This method has the advantage of simplicity, but is defective in other respects, and particularly so in regard to the difference in the quantity of coloring matter in different kinds or specimens of indigo.

The most accurate method is to decompose the chloride of lime confined in a glass tube, over mercury, by means of muriatic acid. The chloride, by this means, would only be decom-

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On what principle has it been proposed to ascertain the goodness of bleaching powder by the quantity of oxygen it contains? How is the goodness of bleaching powder tested by means of a solution of indigo? What is the defect in this method? What is said to be the most accurate method of ascertaining the quantity of chloride in bleaching powder?

posed, and converted into the muriate of lime, while the muriate already formed, would remain as before. By this process the chlorine of the chloride is set free, unmixed, and its quantity readily measured by the tube in which the experiment is made.

There being no standard of the quantity of chlorine which the best bleaching powder ought to contain, it is by the comparison of different specimens only, that the purchaser can be guided.

474. **Disinfecting property of chloride of lime.**—Experiments have long since shown, that chlorine has the power of combining with, or in some other manner, neutralizing, or destroying, the fetid exhalations arising from putrefying substances, and of preventing their deleterious effects. In cases of infectious disease, therefore, it is highly useful. For this purpose, a table-spoonful or two of the powder is mixed with a pint of water, and placed in the sick room, and sprinkled in the rooms adjoining. The fetid effluvia from putrid water, from sink drains, or from any other source, is immediately destroyed by the application of a quantity of the chloride.

By placing a sheet, wet with the chloride of lime water, in the bottom of the coffin, and afterward often sprinkling the shroud with the same, the bodies of the dead may be preserved without offense for many days in the hottest season.

475. **Phosphuret of lime.**—This compound is formed by passing the vapor of phosphorus over fragments of quicklime, at a red heat. The experiment may be performed in the following manner:

Having procured a tube of green glass about a foot and a half long, and half an inch in diameter, stop one end with a cork, or otherwise, and place in it a dram of phosphorus, letting it occupy the closed end. Then holding the tube in a horizontal position, push into it with a wire, or rod, pieces of fresh burned quicklime about the size of peas, until they fill the middle part of the tube, taking care that the lime does not reach the phosphorus by two inches. Then stop the mouth of the tube loosely, to prevent the free access of the air, but leaving room for that in the tube to pass out as it expands.

Next, heat that part of the tube containing the lime red hot,

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Is there any standard of the strength of bleaching powder? What is said of the disinfecting power of chlorine? What is phosphuret of lime? Describe the process of making the phosphuret of lime. When phosphuret of lime is thrown into water, what are the chemical changes produced?

by means of a chafing dish of coals, at the same time keeping the phosphorus cool by a wet rag passed round the end of the tube. When the lime is seen to be at a red heat, bring a hot iron, or lamp, under the phosphorus, which will soon be turned into vapor, and passing over the lime, the two substances combine, and form the phosphuret of lime.

When phosphuret of lime is thrown into water, mutual decomposition ensues, and there rises bubbles of phosphureted hydrogen through the fluid, which take fire on reaching the air. The phosphorus absorbs the oxygen from the water, thus liberating the hydrogen, which combines with a portion of phosphorus, forming the gas above named.

CHAPTER XIX.

ORDER II.

Metals which are supposed to be analogous to Order 1st. They are the metallic bases of the earths. These are,

Magnesium,	Yttrium,	Zirconium.
Glucinum,	Aluminum,	

476. Magnesia, glucina, yttria, alumina, and zirconia, before the galvanic experiments of Sir H. Davy, have been known under the general name of *earths*, and were considered pure elementary substances. When these earths are submitted to the action of a powerful galvanic battery, they all give more or less evidence that their bases are metals, combined with oxygen. Magnesia, for instance, when exposed for a long time to the action of a powerful battery, in contact with mercury, appears to be decomposed; for the mercury becomes enlarged in bulk, and losing its fluidity, show signs of having formed an amalgam with the metallic base of the magnesia. When this amalgam is heated in a close vessel, out of contact with the air, the mercury is driven off, and there remains a dark gray film, of a metallic appearance, which, when exposed to the action of oxygen, is converted into a white powder, having the

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What is the definition of Order 2d? What are the names of the substances belonging to Order 2d? Under what names were these substances known before the experiments of Sir H. Davy? Were they formerly considered compound, or elementary bodies? What is the reason for supposing that magnesia has a metallic base? What is the reason for supposing that alumina has a metallic base?

properties of magnesia. It is therefore concluded, that magnesia has a metallic base, though the metal itself has never been separated in such quantities as to allow any further examination of its properties than those above stated.

When the earth *alumina*, which is the base of alum, is brought into contact with the vapor of potassium at a white heat, and in a close vessel, the potassium is converted into potash. Now, as potassium is converted into potash only by the absorption of oxygen, and as the oxygen could have been derived from no other source except the alumina, such an experiment shows that alumina contains oxygen, and therefore by analogy, there is reason to suppose that alumina is composed of the metal aluminum and oxygen.

477. The other earths above named, when submitted to similar experiments, have each shown that they contained oxygen; and as potash, soda, and lime, are known to be metallic oxides, that is, to consist of a metal combined with oxygen, it is inferred that the earths, possessing similar properties, are also composed of a metal united with oxygen. It is therefore agreed among writers on chemistry, that the bases of these earths should be arranged as metals, under the names above specified; though their existence, with perhaps the exception of magnesium, has never been directly proved.

In consequence of the discovery, or the inference, that the earths possess metallic bases, their names, in conformity with the language of chemistry, are changed from words denoting simple bodies, to such as denote compounds. Thus, the earth formerly called *magnesia*, is now known under the name of *oxide of magnesium*, and the simple term *alumina*, is changed to *oxide of aluminum*, the same language being adopted with respect to all the other earths above named.

PROPERTIES OF THE EARTHS.

478. MAGNESIA, OR OXIDE OF MAGNESIUM.—Pure magnesia is well known as a medicine, under the name of calcined magnesia. This is obtained by exposing the carbonate of magnesia to a red heat. It is white, tasteless, and inodorous, but possesses slight alkaline properties, being capable of changing the blue colors of vegetables to green, and of neutralizing the acids, with

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On what grounds is it believed that the other earths belonging to this order have metallic bases? What are the scientific names of magnesia and alumina, supposing them to be the oxides of metals? How is pure magnesia obtained? What effect does magnesia have on vegetable colors?

which it forms various saline compounds. One of these, the sulphate of magnesia, or Epsom salts, is a well known medicine.

Magnesia, in a few instances, has been found in the native state, but always in small quantities only. That sold by apothecaries is obtained from certain springs, as that of Epsom, where it exists, in combination with sulphuric acid, forming Epsom salts, which is dissolved in the water.

Calcined, or pure magnesia, if exposed to the air, absorbs carbonic acid, and is converted into a carbonate. Hence, a large proportion of that used in medicine, and sold for calcined, is in truth the carbonate, the change being effected by carelessness in exposing the calcined to the air.

479. ALUMINA, OR OXIDE OF ALUMINUM.—The earth alumina is one of the most abundant productions of nature, every description of clay being an aluminous earth, of a greater or less degree of purity. The clay of which bricks, pipes, and earthen-ware are made, consists chiefly of this earth. The ruby and the sapphire, two of the hardest and most beautiful of gems, are also composed of alumina. Pure alumina, for experiment, is most easily obtained from alum, which is a sulphate of alumina and potassa. To obtain the earth, dissolve one part of alum in six parts of boiling water, and when the solution is cold, add one part of carbonate of potash. By this process the sulphate of alumina is decomposed, in consequence of the strong affinity existing between the potash and sulphuric acid, and two new salts are formed, viz., sulphate of potash and carbonate of alumina, the latter being precipitated to the bottom of the vessel. This precipitate being washed, and then exposed to a red heat, to expel the carbonic acid, is pure alumina.

The substance, thus procured, is white, inodorous, soft to the touch, and tasteless. Mixed with water, it forms a mass which is exceedingly plastic, and may be worked into all shapes. The tenacity of every kind of clay is owing to the alumina it contains.

Alumina, being insoluble in water, does not affect the colors of vegetables. It, however, performs the part of an alkali in neutralizing the acids, and forming with them saline compounds.

What is the most common salt of which magnesia is the base? How is pure magnesia converted into a carbonate? How is the uncertainty of magnesia, as a medicine, accounted for? What is the earth of which clay is chiefly composed? What common articles, and what precious stones, are composed of alumina? How may pure alumina be obtained?

480. **Glucina, or oxide of glucinum.**—The earth called glucina has been discovered but in small quantities, being known to exist only in the minerals, emerald, beryl, and euclase. Its name comes from a Greek word signifying sweet, because some of its combinations are sweet to the taste. In some of its properties it resembles alumina, and in others it differs from all the other earths. One of its distinctive properties is that above mentioned, of forming a compound, when dissolved in sulphuric acid, which is sweet to the taste.

481. **Yttria, or oxide of yttrium.**—Yttria resembles alumina and glucina in most of its chemical properties, but differs from them both, in being insoluble in a solution of pure potash. This earth has been found only in a single rare mineral, in Sweden. It forms peculiar salts, when combined with the acids, and is thus known to differ from all the other earths.

482. **Zirconia, or oxide of zirconium.**—This earth is also exceedingly rare, having been detected only in the zircon, a precious stone found in Ceylon, and the hyacinth of France. It resembles alumina and the other earths in being a white soft powder. Its salts are distinguished by being precipitated from their solutions by all the pure alkalies.

Zirconium, the base of this earth, was separated from its oxygen, by the Swedish chemist Berzelius, in 1824. It was in the form of a black powder, which took fire in the open air at a temperature far below a red heat, and burned with a bright flame. The product of the combustion was zirconia. But whether this base is of a metallic nature, has not been decided. It is wanting in one property common to all metals, being a non-conductor of electricity.

483. **Silica, or oxide of silicium.**—Sir H. Davy's experiments on silica led him to suppose, that in common with the earths above described, it had a metallic base, and it was arranged with them, in conformity to this opinion. But more recently, Berzelius has succeeded in decomposing this earth, and has given an account of the properties of its base. From this we learn that silicium is of a dark brown color, without the least trace of a metallic luster. That it is incombustible in the open air, or in oxygen gas, and that it may even be exposed to

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What chemical changes take place when alum, in solution, is mixed with carbonate of potash? What is the appearance of pure alumina? In what minerals does the oxide of glucina exist? What is the meaning of the word glucina, and why is this earth so named? How does yttria differ from alumina and glucina? In what minerals has the earth zirconia been found? How are the salts of zirconia distinguished? What is said of the metallic base of zirconia? What is said of the metallic base of silica? Is the base of silica of a metallic nature?

the flame of the blow-pipe without fusion, and without suffering the least change. It is not dissolved by any of the acids, except a mixture of the nitric and fluoric, with which it readily enters into solution. It is not a conductor of electricity. These properties, and particularly its want of metallic luster and of power to conduct electricity, prove that the base of silica is not of a metallic nature.

Silica, or silex, is a very abundant natural product. It forms a large part of all granitic, or primitive rocks, and mountains, and is the chief ingredient in sandstones, and earthy formations. Rock crystal, or quartz, flint, chalcedony, agate, carnelian, and all other substances of this kind, are composed almost entirely of silex.

484. Silica may be obtained in sufficient purity for most purposes, by heating transparent rock crystal to redness and plunging it into water while hot, and then reducing it to powder.

In this state, silex is a white powder, which feels harsh when rubbed between the fingers, and has neither taste nor smell. It is exceedingly infusible, but may be melted with the compound blow-pipe. It resists the action of all the acids, except the fluoric, which dissolves it with considerable facility. It is dissolved by the fixed alkalies, and hence it would appear that its properties are rather of an acid, than of an alkaline nature. On this account most chemists have called silica an acid, and the compounds which it forms with the alkalies, have been termed *silicates.*

From what has been said, the student will infer that there is yet considerable doubt and uncertainty, in respect to the real nature of silica.

Dr. Thompson, being convinced of its non-metallic nature, arranges it with the simple bodies carbon and boron. There is no doubt, however, from the experiments of Davy and Berzelius, of its compound nature; and that it consists of a base combined with oxygen, has been proved by direct experiment. But that its base is not a metal is proved from its want of luster, and power to conduct the electric fluid, those two properties being essential to all metallic bodies.

485. Glass.—Silex in the form of sand, is a principal article in the manufacture of glass. The common dark colored, or

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What substances are mentioned of which silica forms the principal part? How may pure silica be obtained? What are the properties of silica? What is said of the compound nature of silica?

green glass, is composed of impure sand, which contains oxide of iron, melted with kelp, wood-ashes, or impure potashes. Crown glass, for windows, is composed of white sand, fused with a purer alkali. Plate glass, for looking-glasses, is made of still purer materials; and what is known by the name of flint glass, of which decanters, and other ornamental, or cut glass-ware are made, is composed of the purest sand and alkali, with the addition of a considerable portion of lead, which is added in the form of litharge, or red lead. This is the softest and heaviest kind of glass. It cuts more easily, and withstands the changes of temperature much better than glass containing no lead.

ORDER III.

Metals which decompose water at a red heat. These are,

Manganese,
Zinc,
Cobalt,
Iron,
Tin,
Nickel, and
Cadmium.

486. The power of a metal to decompose water, depends on its affinity for oxygen. In some instances, as in those of potassium and sodium, already given, the metals have so strong an affinity for oxygen, as to absorb it from water, at common temperatures. Other metals do not decompose this fluid at any temperature, such being the 4th order of the present class. Those now to be examined have an affinity for oxygen, which they slowly absorb from the atmosphere, and a part of which they retain at high degrees of heat. But their attraction for oxygen is not in sufficient force to decompose water, except when heated to redness, when the combination is effected with considerable rapidity.

MANGANESE.

Equivalent, 28. Symbol, Mn.

487. This metal always occurs in nature in combination with oxygen, and which it holds with such force as to require the most intense heat for its removal. The metal may, however, be obtained in a pure state, by exposing the black, or peroxide, mixed with a combustible, to the highest heat of a smith's forge. The combustible, which may be pitch, or powdered

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What use is made of silex in the arts? Explain the difference between green glass, crown glass, and plate glass. What is the composition of cut glass? What is the definition of Order 3d? What metals belong to Order 3d? On what property of a metal does its power to decompose water depend? In what state does manganese occur in nature?

charcoal, with which the oxide is mixed, is thus made to absorb the oxygen, and the metal is found at the bottom of the crucible.

Manganese is of a dusky white color, with a specific gravity of 8. When exposed to the air it absorbs oxygen, and soon falls into powder, which afterwards changes its color from gray to brown, and from brown to black, according to its grade of oxidation. When this metal is exposed to a red heat, and the steam of water is passed over it, decomposition takes place, the oxygen of the water combines with the manganese, and the hydrogen is disengaged.

MANGANESE AND OXYGEN.

PEROXIDE OF MANGANESE.

Equivalent, 44. Symbol, MnO_2.

1 eq. Manganese, 28+2 eq. Oxygen, 16.

BLACK OXIDE OF MANGANESE.

488. This compound occurs abundantly in nature, and is known under the name of *black oxide* of manganese. It is found in amorphous masses, of a dark gray or nearly black color, and is commonly mixed with various proportions of sand, oxide of iron, carbonate of lime, or other impurities. In its pure state, it occurs in the form of prismatic crystals, of a dark color, and slightly metallic luster.

In this state the metal contains its full proportion of oxygen, and undergoes no change on exposure to the air, or to a moderate heat. When heated to redness, it parts with one proportion of oxygen, and is converted into a deutoxide. In this manner oxygen gas may be obtained. The peroxide of manganese is of considerable consequence in the arts, and particularly in the formation of chlorine for the manufacture of bleaching powders, and also in furnishing oxygen gas for other chemical uses. The methods for obtaining these gases have already been described.

The peroxide of manganese is composed of

1 proportion of manganese,	28
2 " " oxygen,	16
	44

By what process may metallic manganese be obtained from the oxide? What is the appearance and specific gravity of manganese? Under what circumstances does manganese decompose water?

There are two other oxides of manganese, viz., the *protoxide*, and the *deutoxide*. There is also reason to believe that manganese is capable of combining with such proportions of oxygen as to form acids; but the subject has not been sufficiently investigated to determine the composition or nature of these compounds.

Manganese combines with the acids, and forms a variety of salts, which are either colorless, or of a reddish or pink hue. These salts are found only in the laboratory of the chemist, and are of no use in the arts. At a red heat this metal decomposes water.

IRON, (FERRUM.)

Equivalent, 28. Symbol, Fe.

489. This well known metal has a gray color, and a strong metallic luster, which is much improved by burnishing. Iron is at once the most useful, the most abundant, and the most universally diffused of all the metals. It is found in the mineral, the vegetable, and the animal kingdoms, and in some countries it exists in such quantities as to form mountains of considerable size.

When heated, it becomes soft and malleable, and in this state two pieces may be incorporated, or welded together, by hammering. Its specific gravity is about 8. It is attracted by the magnet, and may itself be made permanently magnetic. This property is of vast consequence to the world, being possessed by no other metals except nickel and cobalt, and by these in a much inferior degree.

490. Affinity for oxygen.—Iron has a strong affinity for oxygen, and when exposed to air and moisture, soon rusts or oxidates on its surface. In a perfectly dry atmosphere, however, it undergoes little or no change, a proof that it absorbs oxygen with more facility from water than from the air. When heated, it attracts oxygen both from air and water, with great rapidity. When the steam of water is passed over iron, at a red heat, the water is decomposed, its oxygen combining with the metal, while the hydrogen is set at liberty. When heated to redness, in oxygen gas, it burns with intense brilliancy. Iron is exceed-

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What is the scientific name for black oxide of manganese? When peroxide of manganese is heated to redness, what chemical change does it undergo? Of what use is peroxide of manganese in the arts? What is the composition of the peroxide of manganese? What is said of the acids of manganese? What is the combining number for iron? What is said of the abundance and usefulness of iron? What is said of the affinity of iron for oxygen? Under what circumstances does iron decompose water? In what does this decomposition consist?

ingly ductile, and may be drawn into wire not exceeding the thousandth part of an inch in diameter; but it can not, like gold and silver, be hammered into thin leaves, and therefore is not highly malleable.

The ores of this metal are very numerous, and some of them highly beautiful and interesting. They are chiefly sulphurets and oxides, but the oxides are the only ores from which the metal is obtained.

Iron has, in a few instances, been found in its native state, mixed with lead and copper, or with some earthy substance. It has also been found in large masses, alloyed with five or six other metals, and called *meteoric iron*, from an opinion that these masses fell from the clouds. Native iron is soft and malleable as it occurs, and does not differ from that which has been reduced from its ores and purified.

Cast-iron contains variable proportions of carbon and oxygen, and in this state it is hard and brittle. These impurities are detached by the process of refining, and then the iron becomes soft and malleable.

491. STEEL.—Steel is made by heating pure iron with carbon, or charcoal, by which it is rendered exceedingly hard and brittle. This change is produced in consequence of the absorption of a portion of carbon by the iron. Steel, therefore, is composed of iron and carbon, and its scientific name is *carburet of iron.*

492. COATING IRON WITH OTHER METALS.—Messrs. Gressel and Redwood, of London, have recently patented the following methods of coating iron with zinc, and other metals. The zinc is melted in an open vessel, and on its surface is placed a layer of chloride of zinc, or a mixture of equal parts of chloride of zinc and chloride of potassium, in the proportion of eight of the former and two of the latter. When the chloride on the surface is in a state of fusion, the sheets of iron to be coated are placed in the melted zinc, and allowed to remain there for a short time, or until a coating of sufficient thickness adheres to it, when it is withdrawn. If any part of the surface is imperfectly covered, this is sprinkled with the sal ammonia, and the sheet of iron again immersed in the zinc bath.

493. TO COAT IRON WITH SILVER.—The iron must first be

What is said of the ductility and malleability of iron? In what state does iron occur as a natural product? What is the ore from which iron is extracted? What is meteoric iron? What are the impurities contained in cast-iron? How is steel made? What is the composition of steel?

covered, or amalgamated with mercury, by the following process: 12 parts, by weight, of mercury, 1 of zinc, 2 of sulphate of iron, 2 of muriatic acid, and 12 of water, are mixed together and heated in an open vessel to about 200 degrees Fahrenheit. Into this the iron is immersed, and while warm, the mercury is rubbed on the surface until it adheres by amalgamation. The silver, having been melted in a crucible, the amalgamated iron being dipped therein, a coating of the silver will be deposited on its surface.

IRON AND OXYGEN.

OXIDE OF IRON.

RUST OF IRON.

494. Iron combines with oxygen in two proportions, forming the blue and red oxides of this metal.

495. **PROTOXIDE OF IRON.**—The black, or protoxide of this metal, is formed by passing dry hydrogen over the red oxide, at a temperature a little below redness. This oxide is composed of 1 equivalent of iron, 28, and 1 equivalent of oxygen, 8. Its combining number, therefore, is 36. Symbol, FeO.

496. **THE BLACK OXIDE OF IRON**, which occurs in the form of scales, when iron is heated, and hammered in the open air, is not a definite compound, but a mixture of the black oxide, and metallic iron.

497. **PEROXIDE OF IRON.**—This is the red oxide, and is known to mineralogists as a native compound, under the name of **RED HEMATITE.** The same article is known to button-makers, and other artists, under the name of *blood stone*, and is employed to polish their work. The peroxide may be prepared by art, by dissolving iron in nitric acid, then precipitating it with ammonia, and heating the precipitate to a little below redness, to drive off the acid. Its color and other properties are like those of the native red oxide. The peroxide of iron is composed of iron, 28, and oxygen, 12.

498. **THE BROWN OXIDE OF IRON** is composed of precisely the same proportions of the metal and oxygen as the red oxide, but in addition to these ingredients, it contains one proportion, or 9 parts of water.

What is the scientific name of steel? What is the method of coating iron with zinc? How may iron be coated with silver? In how many proportions does oxygen combine with iron? What are the names of these oxides? What is the [illegible] of the protoxide? What is the composition of the peroxide of iron? [illegible] brown differ from the red oxide of iron?

The other oxides of iron are either mixtures of the red and blue oxides, or one or both of these oxides containing various impurities. The great number of oxides of this metal, described in books of mineralogy, and differing from each other in color, hardness, and form, arise from such mixtures. Thus, the magnetic oxide of iron, or native magnet, is composed of peroxide of iron, 71, and protoxide 29 to the 100. The brown oxides of iron all contain water, and are, therefore, called *hydrates*. The ochres are of this kind.

Iron combines with carbon, sulphur, iodine, phosphorus, and the different acids. Its compounds are, therefore, exceedingly various, in respect to form, color, and properties. We shall, however, examine only two or three of these compounds here, the salts being reserved for another place.

499. Carburet of iron.—Steel, we have already said, is a carburet of iron. This important metal is manufactured from the iron, by exposing the latter to a long continued red heat, in contact with charcoal. For this purpose, the purest malleable iron, in bars, is employed, and is found to gain in weight, one pound in 150, by the process. Steel, therefore, consists of iron combined with a 150th part of its weight of carbon, which it absorbs from the fire. When iron is perfectly inclosed, and heated with a fragment of diamond, it is converted into steel, in the same manner as when heated with charcoal. This experiment shows the identity of carbon and diamond, the only difference being the color and crystalline form of the latter. It also proves that the hardness of steel is owing to the particles of diamond which it contains.

The native carburet of iron, commonly known under the name of *black lead*, or plumbago, contains 95 parts of carbon and 5 of iron. This substance is infusible at the highest heat of a furnace, and hence is employed in making crucibles and melting-pots. It is also used in making black lead pencils.

500. Sulphide of iron.—This compound occurs as a natural product, and is known to mineralogists and others under the name of *iron pyrites*. It is a yellow brittle substance, often crystallized in the form of cubes, or octohedrons, with their surfaces highly polished. These specimens are generally

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What is the composition of the native magnet? What substances are mentioned with which iron combines? In what proportion is the weight of iron increased by being converted into steel? What is said of converting iron into steel by means of the diamond? What does this experiment prove? What is the composition and the proper name of black lead? What are the uses of black lead? Is sulphuret of iron a natural, or artificial compound?

taken for gold, by those who are ignorant of such matters, and the places where they are found are sometimes kept a profound secret, for years, for fear the owner of the soil should claim a part of the wealth. Every mineralogist, on pronouncing such specimens of no value, has occasionally witnessed the fallen countenance of the applicant, whose hopes and expectations he had thus blasted. Sulphide of iron may also be formed by touching a bar of iron, at a glowing red heat, with a roll of brimstone. The compound will fall down in drops. The natural and artificial sulphurets are composed of precisely the same definite proportions, viz., iron, 28, and sulphur, 16.

ZINC.

Equivalent, 32. Symbol, Zn.

501. Zinc, when pure, is of a bluish white color, and of a striated fracture, presenting the result of a confused crystallization. When rubbed with the fingers it imparts to them a peculiar metallic taste and smell. When cold, this metal is not malleable, but when heated to between 200 and 300 degrees, it becomes both malleable and ductile. If its temperature be raised to 400 degrees, it becomes so brittle as to be readily reduced to powder, in a mortar.

Zinc melts at 680 degrees, and if this temperature be increased, it burns with a bluish flame in the open air. When melted with copper it forms the alloy, well known under the name of *brass.*

502. Calamine.—Zinc never occurs in the native, or pure state, but is always found combined either with sulphur, carbonic acid, or oxygen. The sulphuret of this metal, called *zinc blende*, and the carbonate, called *calamine*, are the ores from which zinc is obtained. The sulphuret being *roasted*, that is, submitted to a low red heat in the open air, to drive off the sulphur, and oxydize the metal, is then melted with charcoal, by which the oxygen is absorbed, and the metal reduced. The calamine is first roasted to drive off the carbonic acid, and is then distilled in iron retorts, by which means the pure metal is obtained. This latter process is said to have been learned of

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What is the appearance of the native sulphuret of iron? What precious metal is this compound sometimes taken for? How may sulphuret of iron be formed artificially? What is the composition of sulphuret of iron? What is the color of pure zinc? Under what circumstances is zinc malleable? In what temperature does zinc melt? What is the composition of brass? Is zinc ever found in the native state? What are the names of the ores of zinc, and of what are they composed? How is zinc reduced from its sulphuret? How is calamine reduced?

the Chinese, and that a man was sent from Europe to China on purpose to obtain the secret. Pure zinc, when exposed to a white heat in a close vessel, will in the same manner sublime, and again condense, unchanged.

503. Malleable brass.—It is well known that brass, as it is usually made, is very brittle, whether hot or cold. This depends, it appears, on the proportions of the zinc and copper, of which it is composed; since it is stated in the London Chemist, that it has recently been discovered in Germany, that by melting together 33 parts of copper and 25 parts of zinc, or 60 parts of copper and 40 parts of zinc, alloys are formed which possess a high degree of malleability.

ZINC AND OXYGEN.

OXIDE OF ZINC.

Equivalent, 40. Symbol, ZnO.

1 eq. Zinc, 32+1 eq. Oxygen, 8.

FLOWERS OF ZINC.

504. When zinc is exposed to a red heat in the open air, it burns with a white flame, and at the same time an oxide of the metal is formed, which, rising by the heat, falls around the place of combustion in the form of white flakes. This substance was formerly called *flowers of zinc*, and sometimes *philosophical wool*. It is an oxide of the metal, and the only one known. When this oxide is collected, and again submitted to the fire, it does not rise, as before, but melts into a clear glass.

When the vapor of water is brought into contact with metallic zinc at a red heat, the water is decomposed, the zinc combining with its oxygen, and forming an oxide, in the same manner as is done in the open air. Both these oxides are composed by weight of

1 equivalent of zinc, . . .	32
1 " " oxygen, . .	8
Combining number for oxide of zinc,	40

How may malleable brass be made? How is the oxide of zinc formed? What was this oxide formerly called? How may zinc be made to decompose water? What is the composition of oxide of zinc, and what is its combining number?

CADMIUM.

Equivalent, 56. Symbol, Cd.

505. Cadmium is one of the new metals, having been discovered in certain ores of zinc, in 1817. This metal in color and luster resembles tin, but is harder and more tenacious. It is both ductile and malleable to a considerable degree. Its specific gravity is nearly 8.5. It fuses at a temperature something less than 500 degrees, and at a little higher heat it rises in vapor, and condenses in globules like mercury.

When cadmium is heated in the open air, like many other metals, it absorbs oxygen, and is converted into an oxide. It is readily dissolved by the nitric acid. When heated in contact with the vapor of water, the fluid is decomposed, and an oxide of the metal is formed.

Cadmium combines, so far as is known, with only one proportion of oxygen. This oxide is composed of

Cadmium,	1 equivalent,	56
Oxygen,	1 "	8
		64

Cadmium, like the other metals, forms salts by combination with the acids. But these compounds are little known, and of no value.

TIN, (STANNUM.)

Equivalent, 58. Symbol, Sn.

506. Tin must be examined in the state of grain, or block tin; what is commonly called tin, being sheets of iron, merely covered with this metal.

Tin is procured from its native oxides, by heat and charcoal, on the same principle that has already been described for iron and several other metals. The ores of tin are only two, viz., an oxide and a sulphuret. This metal is not readily oxidized by exposure to the atmosphere, though the brilliancy of its surface is soon tarnished. It is highly malleable, but not equally ductile, its tenacity not being sufficient to allow its being drawn into fine wire. Its specific gravity is 8. When heated to

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What is cadmium? What other metals does cadmium resemble? Is this a brittle or a malleable metal? What is the specific gravity of cadmium? What is the composition of oxide of cadmium? Of what metal is the sheet tin chiefly composed? How is tin procured from its oxide? What are the only ores of tin? Is tin readily oxidized by exposure to the air or not? What is said of the malleability and ductility of tin?

whiteness, it takes fire in the open air, and burns with a white flame, being at the same time converted into an oxide; at a red heat it decomposes water.

Tin is a highly useful metal, being employed for many valuable purposes in the arts and conveniences of life. Thin sheets of iron, being dipped into melted tin, receive a coat of the metal, and are thus prevented from rusting. This is called *sheet tin*, and is the article of which the common tin ware is made. Tin foil, that is, tin rolled into thin sheets, is used for many purposes. Electrical jars are coated with it, and the backs of looking-glasses are formed of an amalgam of tin foil and mercury. Block tin forms a part of Britannia ware, of princes' metal, of pewter, speculam metal, &c.

TIN AND OXYGEN.

507. Tin combines with oxygen in two proportions: The first, or the protoxide, is formed when the metal is kept for some time in fusion in the open air. At this temperature it absorbs oxygen from the atmosphere, and is converted into a gray powder. This powder is the protoxide, and is composed of

1 equivalent of tin,	58
1 " " oxygen,	8
	66

This oxide is soluble in acids and in ammonia. The second, or peroxide of tin, is prepared by dissolving the metal in nitric acid, slightly diluted with water. It is a powder of a yellow color, and is composed of

1 equivalent of tin,	58
2 " " oxygen,	16
	74

This oxide, when melted with glass, forms white enamel.

Tin combines with sulphur, chlorine, and the acids, forming a variety of compounds, some of which are occasionally used in the arts.

What is the specific gravity of tin? Into what is this metal converted when burned in the open air? How is sheet tin made? What are the principal uses of tin? In how many proportions does tin combine with oxygen? How is the protoxide of tin formed? What is the composition of the protoxide of tin? How is the peroxide of this metal prepared? What is the quantity of oxygen contained in the peroxide of tin?

ORDER IV.

508. *Metals which do not decompose water at any temperature.* These are,

Arsenic,
Molybdenum,
Chromium,
Tungsten,
Antimony,
Uranium,
Columbium,
Cerium,
Titanium,
Bismuth,
Copper,
Tellurium,
Lead,
and
Vanadium.

The last order includes all such metals as attract oxygen with sufficient force, when heated to redness, to decompose water. The present division absorb and retain oxygen at high temperatures, but none of them attract that principle, even at the highest temperatures, with sufficient force to decompose water.

ARSENIC.

Equivalent, 75. Symbol, As.

509. There are no mines worked merely for the purpose of obtaining arsenic, the arsenious acid, the only form in which it is used, being procured by the process of roasting the ores of cobalt. The ores of the latter metal, being heated in furnaces with long chimneys, the acid rises and attaches itself to the sides of the chimney, in layers, or cakes. After a considerable quantity has been accumulated in this manner, it is scraped off, and purified by a second sublimation, when it forms the well known poison called *white arsenic*, or *oxide of arsenic.*

From the white oxide the metallic arsenic is procured, by heating this with a combustible.

In legal investigations, where there is a suspicion of poisoning with arsenic, it sometimes happens that justice will depend on the decision of the chemist, whether arsenic might not have been the cause of death. In such cases, very minute portions of arsenic may be detected by means of a combustible and a glass tube, in the following manner: Let the matter suspected to contain the poison, be well dried at a low heat; then mix it with five or six times its weight of powdered charcoal, and put the mixture into a thin glass tube, closed at one end. If now heat be gradually applied to the tube until it becomes red, the

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What is the definition of Order 4th? What are the names of the metals arranged under the 4th order? Are any mines worked merely to obtain arsenic? How is the oxide of arsenic procured? How may arsenic be reduced from its oxide to the metallic state? What is the appearance of pure arsenic?

metal, if arsenic be present, will rise and coat its inside, showing a brilliant metallic luster, similar to that of steel. If it is found that, on heating a small piece of this metal, it rises in white vapor and gives the smell of garlic, it is arsenic beyond doubt.

The structure of metallic arsenic is crystalline, and its specific gravity about 8. When heated to about 360 degrees, it sublimes, without fusion, its melting point being far above that at which it becomes volatile. If the metal is heated in the open air, it is converted into the arsenious acid, and again becomes poisonous as before; but, while in the metallic form, arsenic has no action on the system, and, therefore, is not a poison.

ARSENIC AND OXYGEN.

ARSENIOUS ACID.

Equivalent, 91. Symbol, AsO_3.
1 eq. Arsenic, 75+2 eq. Oxygen, 16.

WHITE ARSENIC. OXIDE OF ARSENIC.

510. We have stated above, that when metallic arsenic is heated in the open air, it is converted into a white substance called *oxide* of arsenic. This is the *arsenious* acid of chemists. It differs from the oxides of metals in possessing acid properties. It is slightly soluble in water, reddens vegetable blue colors, and combines with alkalies, forming salts called *arseniates*. The arsenite of potash, usually called *Fowler's solution* of arsenic, has been long employed in medicine, as a remedy for eruptive, and other diseases.

ARSENIC AND SULPHUR.

SULPHURETS OF ARSENIC.

511. Sulphur combines with arsenic in two proportions, forming compounds which are known by the names of *orpiment*, and *realger*. These compounds are, both of them, natural products, and may also be formed by art. Realger is of a red, or scarlet color, with a shining semi-metallic luster, and is com-

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What is the specific gravity of arsenic? Is metallic arsenic a poison? How is arsenious acid formed? What is the common name of this acid? What is the form of arsenious acid? What are the salts called which arsenious acid forms with the salifiable bases? What use is made of arsenite of potash? In how many proportions does sulphur combine with arsenic? What is realger? What is its composition? How does orpiment differ from realger?

posed of 75 parts of metallic arsenic, and 16 parts, or one proportion, of sulphur.

Orpiment has a rich yellow color, and a foliated structure. Its luster is shining, and somewhat metallic, and it is readily separated into layers, like mica. This is composed of 75 parts, or one atom of metallic arsenic, and 24 parts, or one atom and a half of sulphur.

Orpiment is employed as a paint under the name of *King's Yellow.*

CHROMIUM.

Equivalent, 28. Symbol, Cr.

512. The metal chromium has been detected only in the two native compounds, *chromate of lead*, and *chromate of iron.* In these two salts, the metal chrome exists in combination with so much oxygen as to constitute an acid, which is united to the oxides of lead and iron, forming the compounds above named. Arsenic, as shown above, forms an acid with oxygen in the same manner, and we shall see presently that several other metals, when combined with oxygen, perform the office of acids.

Chromium has been procured only in very small quantities, by exposing its acid mixed with charcoal, to the highest temperature of a smith's forge. It is a brittle metal, of a grayish white color, and very infusible. Its specific gravity is 6.

Chromium combines with oxygen in three proportions, forming the following compounds:

		Chrome.		Oxygen.
Protoxide,	composed of	28	and	8.
Deutoxide,	" "	28	"	16.
Chromic acid,	" "	28	"	24.

The oxides of chrome are of no importance in the arts, but the chromic acid forms colored salts with the oxides of the metals, which are extensively employed in painting and coloring.

The chromic acid may be obtained in a separate state, by boiling the native chromate of lead in powder, with twice its weight of carbonate of potash, and afterward saturating the

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What use is made of orpiment? What is chromium? In what native compound is chromium found? In what state does chromium exist in these compounds? How has chromium been prepared? What is the color and what are the properties of chromium? In how many proportions does chromium combine with oxygen? What are the names of these compounds? Of what use is the chromic acid? How may pure chromic acid be obtained?

alkali with dilute sulphuric acid. The sulphate of potash thus formed, will subside, leaving the chromic acid in solution, which, on evaporation, will yield crystals of chromic acid.

These crystals are of a ruby red color, and when dissolved in water, possess all the properties of an acid.

513. The useful compounds formed by combining chromic acid with salifiable bases, are prepared from chromate of potash in solution. The latter salt is made by heating to redness the native chromate of iron with an equal weight of nitrate of potash. By this process, the chromate, which was in the state of an oxide, is converted into chromic acid, by the oxygen of the nitrate, the acid at the same time combining with the potash of the niter. The ignited mass is then dissolved in water, neutralized by nitric acid, and the solution concentrated by evaporation, when the chromate of potash shoots into crystals, of a yellow color.

The chromate of lead, a beautiful paint, at present largely employed under the name of *chrome yellow*, is made by mixing acetate, or sugar of lead, dissolved in a large quantity of water, with solution of chromate of potash. A double decomposition of these two salts is thus effected, and acetate of potash and chromate of lead are formed. The acetate remains in solution, while the chromate being insoluble in water, falls down in the form of an orange colored, or yellow powder. This powder being separated from the liquid, and dried, forms the beautiful pigment in question.

MOLYBDENUM.

Equivalent, 48. Symbol, Mo.

514. The native sulphuret of molybdenum is a ponderous mineral, which occurs in masses, or is disseminated in other minerals. Its structure is foliated, and its luster like that of lead recently cut. When this compound is reduced to fine powder, and digested in nitro-muriatic acid, the sulphur and metal are both acidified by the oxygen imparted to them by the nitro-muriatic acid. On heating the solution, the sulphuric acid thus formed is expelled, while the molybdic acid remains in the form of a heavy white powder. From this powder the

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What is the color and form of this acid? How is the chromate of potash prepared? How is the chromate of lead made from the chromate of potash? What is the color and use of chromate of lead? How is the native sulphuret of molybdenum described? By what process is molybdic acid procured? How is the metal obtained from this acid?

metallic molybdenum may be obtained by exposing it, mixed with charcoal, to the strongest heat of a smith's forge.

This metal has never been obtained, except in very small quantities, and in the form of brilliant white globules, contained in a blackish mass. When heated in the open air, it is soon converted into *molybdic acid.*

Molybdic acid is in the form of a white powder, which has a sharp metallic taste, reddens vegetable blues, and forms salts with the alkalies, called *molybdates.*

This acid is composed of 1 proportion of molybdenum, 48, and 3 proportions of oxygen, 24.

TUNGSTEN, (WOLFRAM.)

Equivalent, 95. Symbol, W.

515. The tungstate of iron, is a brownish black mineral, which is found both massive and crystallized. Its specific gravity is upward of 7, and when broken it presents a foliated structure, and a luster somewhat metallic.

This mineral, by the miners, is called *wolfram*, and is composed of tungstic acid and oxide of iron, with a portion of the oxide of manganese.

From this mineral the tungstic acid may be procured, by the action of muriatic acid, in the form of a yellow powder.

When tungstic acid is mixed with charcoal, and exposed to an intense heat, the metal is deprived of its oxygen by the charcoal, and appears in its pure form.

Tungsten has a specific gravity of 17.4, being next to platina, gold, and iridium, the most dense body known. It is nearly equal to steel in hardness, and is one of the most infusible of the metals. When heated in the open air, it is reconverted into tungstic acid. This acid is composed of 95 parts of tungsten and 24 parts of oxygen, consequently 95 is the atomic weight of this metal, and 119 the equivalent number for tungstic acid. No use has been made of this metal, or any of its compounds.

COLUMBIUM, (TANTALUM.)

Equivalent, 92. Symbol, Ta.

516. This metal was discovered by Mr. Hatchett, of London, in a black mineral, which was sent to the British Museum, by

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What is the appearance of molybdenum? What are the salts called which molybdic acid forms with the salifiable bases? What is the appearance of tungstate of iron? How is tungstic acid procured?

Governor Winthrop, of Connecticut. The mineral came from New London, and is said to have been found near the residence of the governor.

Columbium, like tungsten, exists in its natural state, combined with so much oxygen as to perform the part of an acid, and is found united to the oxides of iron, or manganese.

This metal is of an iron gray color, and considerable metallic luster. Its specific gravity is 5.5.

Columbic acid is composed of columbium, 92, and oxygen, 8. Its equivalent number, therefore, is 100.

ANTIMONY, (STILBIUM.)

Equivalent, 129. Symbol, Sb.

517. The only ore from which the antimony of commerce is obtained, is the sulphuret. From this native compound the pure metal is separated, by heating it with half its weight of iron filings in a covered vessel. By this process the sulphur unites with the iron, while the fused antimony is drawn off at the bottom of the vessel.

Antimony is a brittle metal, of a bluish white color, and considerable luster. Its structure is lamellated, or it consists of layers, which are the result of an imperfect crystallization. It is fused at about 800 degrees, and when slowly cooled, may be crystallized in octohedrons. By exposure to the air it tarnishes, though not so readily as several other metals. Its specific gravity is about 7.

ANTIMONY AND OXYGEN.

518. Oxygen combines with antimony in three proportions, forming the protoxide, composed of antimony, 129, and oxygen, 8; the deutoxide, consisting of antimony, 129, and oxygen, 12; and the peroxide, composed of antimony, 129, and oxygen, 16.

The deutoxide combines with alkalies, and forms salts; it is therefore called *antimonious acid*, and the salts so formed are *antimonites.*

What is the process for procuring tungsten from tungstic acid? What is the specific gravity of tungsten? What are the properties of tungsten? What is the composition of tungstic acid? Whence came the mineral in which columbium was first discovered? In what state does columbium exist combined with iron? What is the specific gravity of columbium? What is the ore from which antimony is obtained? In what manner is this metal obtained from its ore? What is the color and what the specific gravity of antimony? In how many proportions does oxygen combine with antimony? What are the oxides called?

The peroxide also performs the office of an acid, and combines with alkalies, forming salts, called *antimoniates*, the acid itself being the *antimonic*.

Formerly, there were at least forty different preparations of antimony, known and used in medicine. At present this number is reduced to three or four, and of these only one is in general use, viz., the *tartrate of antimony and potassa*, or *tartar emetic*.

ANTIMONY AND SULPHUR.

519. The native sulphuret of antimony, as stated above, is the only ore from which the metal is extracted. This is generally found in compact masses, though it sometimes occurs in long crystals, interlacing each other. It is of a leaden gray color, with a metallic luster.

The same compound may be formed by fusing antimony and sulphur together, or by transmitting sulphureted hydrogen through a solution of tartar emetic.

Sulphuret of antimony is composed of

Antimony,	1	equivalent,	129.
Sulphur,	1	"	16.

URANIUM.

Equivalent, 60. Symbol, U.

520. This metal was first detected in a mineral found in Saxony, which, from its black color, was called *pitchblende*. This ore, now called *black oxide of uranium*, contains uranium in the state of an oxide, mixed with the oxides of iron and lead.

The metal is reduced from its oxide to the metallic state, with great difficulty, even in the laboratory of the chemist. According to Klaproth, who discovered it, uranium is of a dark gray color, with a metallic luster, and granular texture. It is soluble in nitric acid, fuses only at the highest temperature, and affords a deep orange color to enamel. Its specific gravity is about 8.

Chemists are acquainted with two oxides of this metal. The protoxide is composed of uranium, 60, and oxygen, 8. The combining number of the protoxide is therefore 68.

What is the composition of sulphuret of antimony? What is the ore of uranium called? What is the appearance of uranium? What is its specific gravity? How many oxides of this metal are known? What is said of the native protoxide of this metal? What use is made of this oxide?

The peroxide consists of 1 proportion of uranium, 60, and 2 proportions of oxygen, 16; so that the equivalent number for the peroxide is 76.

The protoxide occurs as a natural product, of a dark emerald green color, and shining luster. It is often found attached to other minerals, in the form of scales, or in bundles of crystals, variously grouped, or interlacing each other, affording one of the most beautiful products of the mineral kingdom. This oxide is also formed by art, and is employed to give a black color to porcelain, the change from green to black being produced by the heat of the porcelain furnace.

CERIUM.

Equivalent, 46. Symbol, Ce.

521. The chemists have proved that a metal called *cerium* exists in a reddish brown mineral found in Sweden, and called *cerite*, or *siliceous oxide of cerium;* and also in a mineral found in West Greenland, and called *Allanite.*

The properties of this metal are little known, it having never been obtained, except in minute quantities, not larger than a pin's head.

It has, however, been ascertained, that cerium combines with oxygen in two proportions, and that its combining or equivalent number is 46. These oxides are composed of cerium, 46, and oxygen, 8, forming the protoxide, whose equivalent, therefore, is 54. The deutoxide contains the same quantity of metal, with one and a half proportions of oxygen. Its equivalent is, therefore, 58.

LANTHANIUM.

Equivalent, 48. Symbol, La.

522. Lanthanium was discovered by Mosander, in 1839, mixed with cerium, in an ore found in Sweden. Its name is from the Greek, and signifies to *lurk*, or *elude*, in allusion to its remaining unknown so long, its oxide having been confounded with that of cerium. One of its oxides is of a brick-red color, and its basic powers are said to be very energetic. Very little is yet known of its properties.

Mosander has quite recently announced the discovery of

What is said of the existence of the metal cerium? When and by whom was lanthanium discovered? What is known of this metal? What is said of the oxide of cerium? From what ore is the metal cobalt obtained? What is zaffree? What is smalt? What is the use of the oxide of cobalt?

another new metal found in the ores of cerium, which he called *Didymium.* Of it we know nothing.

COBALT.

Equivalent, 30. Symbol, Co.

523. The ore from which this metal is extracted, is called *arseniacal cobalt.* It is found in primitive rocks, both disseminated and in veins, associated with nickel, silver, bismuth, arsenic, and copper.

524. Zaffree.—When this ore of cobalt is heated in contact with the air, the arsenic is expelled in the form of arsenious acid, and the sulphur, which it also contains, is converted into sulphurous acid gas, and escapes. By this process, the ore commonly loses more than half its weight, and there remains in the furnace an impure oxide of cobalt, called *zaffree.*

When zaffree is heated with sand and potash, there is formed a glass of a beautiful blue color, which, when pulverized, is extensively known and used under the name of *smalt.* The blue color of porcelain and earthenware, is produced entirely by this oxide of cobalt. Paper and linen, also, receive their bluish tinge from this oxide.

From the oxide of cobalt, or zaffree, the metal may be obtained by heating that substance in contact with some carbonaceous matter. If it is intended to obtain the metal in its pure state, the zaffree must first be purified from the iron, or other metals, which it may contain.

525. Metallic cobalt.—Cobalt is a brittle metal, of a reddish brown color, and slightly metallic luster. It is fused with difficulty. Its specific gravity is 8.5. It is attracted by the magnet, and is capable of being permanently magnetic. Muriatic or sulphuric acid acts but slightly on this metal, but it is readily soluble in nitric acid.

Cobalt does not attract oxygen by exposure to the air, but by a long continued and strong heat, it is converted into an oxide of a deep blue or nearly black color. The atomic weight of cobalt has been lately determined.

526. Sympathetic ink.—This metal is the base of that curious liquid called *sympathetic ink,* and which may be prepared in the following manner:

How may metallic cobalt be obtained from the oxide? What is the appearance of cobalt? What is the specific gravity of cobalt? What is said of the magnetic property of cobalt? What acid is the proper solvent of cobalt? What is the method of preparing sympathetic ink?

Dissolve one part of cobalt, or zaffree, in four parts of nitric acid, and assist the solution by heat. To this solution add one part muriate of soda, and four times as much water as there was acid.

Characters written on paper, with this ink, are illegible when the paper is cold, but become plain, and of a beautiful green color, when the paper is warmed. This experiment is rendered still more pleasant by drawing the trunk and branches of a tree, in the ordinary manner, and then tracing the leaves with the solution of cobalt. In winter such a tree will appear without leaves, except when warmed, but in the summer, particularly if placed in the sun, it will be covered with beautiful green foliage. Screens, painted with this solution, will show their green when in use, but will immediately begin to fade when carried away from the fire.

NICKEL.

Equivalent, 28. Symbol, Ni.

527. Nickel is generally found mineralized by the acids of arsenic. The Saxon ores, among which this metal is found, are mixtures of lead, copper, iron, cobalt, and arsenic, combined with sulphur and oxygen. In nearly every instance, where meteoric iron, or other meteoric products have been analyzed, they have been found to contain this metal.

Nickel, with zinc and copper, melted together, form *German-silver*, of which large quantities are manufactured.

Nickel has a strong metallic luster, and is nearly the color of tin and silver. It is both ductile and malleable, and like iron and cobalt, is attracted by the magnet, and may be made permanently magnetic. Its specific gravity, after being hammered, is 9. It is exceedingly infusible, and suffers no change at common temperatures, when exposed to the air; but is slowly oxidized at a red heat. The muriatic and sulphuric acids do not act on nickel, but it is readily oxidized and dissolved in nitric acid.

Nickel combines with two proportions of oxygen. The protoxide is composed of nickel, 28, and oxygen, 8. The peroxide of nickel, 28, and oxygen, 16=44.

What are the peculiar properties of this ink? With what is nickel combined in the natural state? What is said of the existence of nickel in meteoric products? Is this metal of any use in the arts? What is the appearance of nickel? What is said of its magnetic property? What is its specific gravity? In what acid does nickel dissolve?

BISMUTH.

Equivalent, 72. Symbol, Bi.

528. Bismuth occurs native, and in combination with sulphur, oxygen, and arsenic. That which is employed in the arts and in commerce, is derived chiefly from the native metal. Bismuth has a reddish white color, a brilliant luster, and a foliated structure. It fuses at 476 degrees, being, with the exception of tin, the most fusible of the solid metals. When slowly cooled, this metal may be obtained in octohedral crystals. Its specific gravity is 10.

Bismuth enters into the composition of printing type; and its oxides are employed as paints, and in medicine.

BISMUTH AND OXYGEN.

OXIDE OF BISMUTH.

Equivalent, 80. Symbol, BiO.

1 eq. Bismuth, 72+1 eq. Oxygen, 8.

FLOWERS OF BISMUTH.

529. Bismuth combines with oxygen in only one proportion, forming a yellowish white oxide. This may readily be formed by submitting the metal to a strong heat in the open air. It takes fire and burns with a blue flame, while the oxide falls down in the form of powder.

Bismuth is not readily soluble in the muriatic or sulphuric acids, but the nitric acid dissolves it with facility, forming nitrate of bismuth.

When nitrate of bismuth, either in crystals or in solution, is thrown into water, a copious precipitate subsides, in the form of a beautifully white powder. This is the *subnitrate* of bismuth, and was formerly known under the name of *magistery of bismuth.* This is employed as a cosmetic powder for whitening the complexion, but it is a dangerous substance for such a purpose, since, if it happens to be exposed to sulphureted hydrogen, it turns black, thus exposing the wearer to mortification and detection.

What are the states in which bismuth is found? What is the color of bismuth? What are the uses of bismuth? In how many proportions does this metal combine with oxygen? How may this oxide be formed? What use is made of the subnitrate of bismuth? What is said of the existence of titanium? What is said of the native oxide of titanium?

TITANIUM.

Equivalent, 24. Symbol, Ti.

530. Titanium has hardly been seen in its pure metallic state, but the analysis of its oxides proves that such a metal exists.

The ores of this metal are considerably numerous, and are widely disseminated. The native oxides of titanium sometimes occur in long striated, acicular crystals, of a reddish brown color, and shining metallic luster. Such crystals are sometimes contained in transparent pieces of quartz, forming specimens of singular beauty.

The artificial oxides of this metal are white, and are obtained by difficult processes. They hold their oxygen with such tenacity that all attempts to reduce them, by means of heat and a combustible, in the usual manner, have failed.

The equivalent numbers of these acids have not been determined with certainty.

TELLURIUM.

Equivalent, 66. Symbol, Te.

531. This is an exceedingly rare metal, being hitherto found only in the gold mines of Transylvania, and at Huntington, in Connecticut. It occurs in the metallic state, associated with gold and silver, lead, iron, and sulphur. The color of tellurium is between those of zinc and lead; texture laminated, like that of antimony, which it also resembles in some of its properties. It melts at about 600 degrees; has a specific gravity of 6.11; is brittle, and easily reduced to powder. When heated before the blow-pipe, it takes fire, burns rapidly with a blue flame, and is dissipated in gray fumes, which are an oxide of the metal.

This oxide, which is the only one tellurium forms, is composed of 66 parts of this metal and 8 parts of oxygen; so that 66 is the atomic weight of tellurium, and 74 the equivalent of its oxide.

COPPER, (CUPRUM.)

Equivalent, 32. Symbol, Cu.

532. Copper is found native, also combined with sulphur, with oxygen, with carbonic acid, arsenic acid, sulphuric acid,

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Where have the ores of tellurium been found? In what state does tellurium occur? What is the color of tellurium? What is the composition of the oxides of tellurium? What are the substances with which copper is found combined?

muriatic acid, and with several of the metals. Its ores are very numerous, and some of them highly beautiful and interesting.

The uses of this metal are numerous, and well known. In the metallic state, it forms a part of *brass*, of *pinchbeck*, of *Dutch gold*, and many other alloys.

When dissolved in various acids, it forms compounds which are employed for a great variety of useful purposes.

The green pigment, *verditer*, is a nitrate of copper, precipitated by carbonate of lime. *Verdigris* is an acetate of copper. *Mineral green* is a sulphate of copper, precipitated by caustic potash.

Copper receives a considerable luster by polishing, but soon tarnishes when exposed to the open air. Its specific gravity is 8.78, and is increased by hammering. It is malleable and ductile, and its tenacity is inferior only to iron. It hardens when heated and suddenly cooled. At a red heat, with access to air, it absorbs oxygen, and is converted into the peroxide, which appears in the form of black scales.

Nitric acid acts on this metal with vehemence, and it is dissolved slowly in the muriatic and sulphuric acids. The vegetable acids, as vinegar, also dissolve copper when exposed to the air, but not otherwise, the oxygen of the atmosphere assisting in the oxidation of the metal.

COPPER AND OXYGEN.

PROTOXIDE OF COPPER.

Equivalent, 40. Symbol, CuO.

1 eq. Copper, 32 + 1 eq. Oxygen, 8.

RED OXIDE OF COPPER.

533. The red, or protoxide of copper, is found native in the form of regular octohedral crystals, variously truncated, and forming specimens of great beauty. It may also be prepared artificially, by mixing 64 parts of copper filings with 80 parts of the peroxide in powder, and heating the mixture to redness in a close vessel. By this process, the copper filings attract one proportion of oxygen from the peroxide, which contains twice the quantity of oxygen contained in the protoxide. Thus

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What are the principal uses of copper? What is the specific gravity of copper? How may copper be converted into a peroxide? What acids dissolve this metal? In what form does the protoxide of copper occur? How may the protoxide of copper be prepared by art? Explain how the process for forming the protoxide of copper illustrates the law of definite proportions.

the quantity of oxygen is equalized, and the whole is converted into the protoxide.

This experiment affords a very simple illustration of the law of definite proportions. Eighty parts of the peroxide of copper contains 32 parts of the metal, and 16 of oxygen. When this quantity is heated with 32 parts of copper, 1 proportion, or 8 parts of oxygen, leaves the peroxide, and unites with the copper, thus making, in the whole, 112 parts of the protoxide, the copper gaining 8, and the peroxide losing 8, the number for each becomes 40, the equivalent for the protoxide.

PEROXIDE OF COPPER.

Equivalent, 48. Symbol, CuO_2.

1 eq. Copper, 32+2 eq. Oxygen, 16.

534. This oxide is said to be found in the native state. By art, it may be formed by keeping thin pieces of copper at a red heat exposed to the air, or by heating the nitrate of copper to redness.

This oxide is dark brown, or nearly black. When heated alone, it undergoes no change, but if heated in a close vessel, with charcoal, or other combustible, it parts with the whole of its oxygen, and is reduced to the metallic state. It combines with most of the acids, and produces salts of a green or blue color.

Copper combines with sulphur, and forms a sulphuret of the metal. This compound occurs native, and may be formed by heating a mixture of copper filings and sulphur.

LEAD, (PLUMBUM.)

Equivalent, 104. Symbol, Pl.

535. In a few instances lead has been found in the native state; but it most commonly occurs combined with sulphur, forming the sulphuret, of a bluish gray color, and strong metallic luster. This compound is known under the name of *galena*, and is the ore from which the lead of commerce is exclusively obtained.

The color and common properties of lead are well known. Its specific gravity is 11. In tenacity, it is inferior to all the

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How may the peroxide of copper be formed? How may the peroxide of copper be reduced to its metallic state? What is the composition of the sulphuret of copper? In what state is lead chiefly found? What is the common name for sulphuret of lead? What is the specific gravity of lead?

ductile metals. It fuses at about 600 degrees, and when slowly cooled, may be obtained in octohedral crystals. When newly cut, it has a brilliant metallic luster, but is soon tarnished by exposure to the air.

Lead is not oxidized by moisture without the contact of air, and hence it may be kept under pure water, for any length of time, without change. But if water be placed in an open vessel of lead, the metal is slowly oxidized, and a white crust is formed, at the points of contact between the lead, water, and air, which is a carbonate of the protoxide of lead. Hence, as the salts of this metal are poisonous, leaden vessels open to the air, should never be employed to contain water for culinary purposes.

The sulphuric and muriatic acids act slowly upon this metal. Concentrated sulphuric acid produces so little action on it, that the acid is made in chambers lined with lead. Nitric acid is the proper solvent of this metal. The solution, when evaporated, deposits whitish opaque crystals of nitrate of lead.

LEAD AND OXYGEN.

536. There are three oxides of lead, which are thus constituted:

	Lead.	Oxygen.
Protoxide,	104+	8=112.
Deutoxide,	104+	12=116.
Peroxide,	104+	16=120.

537. **Protoxide of lead.**—This oxide is procured in purity, when a solution of the metal in nitric acid is precipitated by potash, and the precipitate dried. It is of a yellow color; is insoluble in water, and fuses at a red heat. The same oxide is formed by heating lead in the open air, and is known in commerce by the name of *massicot.* When massicot is partially fused, in contact with the air, it becomes of a reddish color, and is known by the name of *litharge.* This appears to be a mixture of the protoxide and deutoxide of lead. Litharge is mixed with oil used in painting, in order to make it dry more rapidly. It is probable that this effect is produced by the oxygen, which the litharge imparts to the oil.

What is said of the oxidation of lead when kept under water? Under what circumstances does water become poisonous when kept in leaden vessels? What is said of the action of different acids on lead? How many oxides of lead are there, and what is the composition of each? What is massicot? How is litharge prepared? What is the use of litharge?

The well known pigment called *white lead*, is a carbonate of the protoxide. This substance is prepared by placing rolls of thin sheet lead in pots containing vinegar. The vinegar imparts its oxygen to the metal gradually, and probably prepares it for the absorption of carbonic acid from the atmosphere. Or possibly the lead may be dissolved by the acetic acid, and this acetate in its forming state decomposed by the carbonic acid of the atmosphere, in the same manner that the chloride of lime is decomposed, and changed into a carbonate by exposure to the air. White lead was formerly considered a peculiar oxide, but analysis shows that it is a compound of the yellow oxide, and carbonic acid.

538. DEUTOXIDE OF LEAD.—This is the *red lead* of commerce, and is extensively used as a pigment, and in the manufacture of flint glass. It is formed by heating litharge in a furnace so constructed that a current of air constantly passes over its surface. In this manner, the litharge, which is chiefly a protoxide, is converted into a deutoxide, by absorbing another proportion of oxygen from the air.

When red lead is heated to redness, it gives off pure oxygen, and is reconverted into the deutoxide.

539. PEROXIDE OF LEAD.—This is formed by the action of nitric acid on red lead. The red lead, or deutoxide, is decomposed by the acid, and resolved in the protoxide which it dissolves, and converts into the peroxide, which being insoluble, falls down in the form of a puce colored powder. This oxide is insoluble in any of the acids. When heated it gives off large quantities of oxygen gas, and is resolved into the protoxide.

540. SULPHURET OF LEAD.—This compound occurs very abundantly as a natural product, and may be formed by fusing a mixture of lead and sulphur.

The lead of commerce, as above stated, is obtained exclusively from this ore, which is generally known under the name of *galena*. The metallic lead is easily obtained from the sulphuret. The ore being placed in the furnace, is gradually heated with small wood, or faggots, to drive off the sulphur. Afterwards, charcoal and lime are thrown in, and the heat is increased. As some portions of the lead become oxidated by exposure to the air and heat, the charcoal reduces these portions

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What is the composition of white lead ? How is white lead prepared ? What is the deutoxide of lead ? How is red lead prepared, and what is its use ? What proportion of oxygen does the deutoxide contain ? How is the peroxide of lead formed ? What are the properties of the peroxide of lead ? How is lead reduced from the sulphuret ?

by the absorption of their oxygen, and at the same time increases the heat. The lime combines with the sulphuric acid, which is formed by the union of the sulphur of the metal, the oxygen of the air, and the water of the wood, and forms a sulphate of lime. Meantime, the metallic lead, thus reduced, runs down into the lower part of the furnace, where it is drawn off into proper vessels.

All the salts of lead act as poisons, with the exception of the sulphate, which Orfila has proved is not deleterious. The same author has shown that the acetate, or sugar of lead, is decomposed in the stomach by sulphate of magnesia, or Epsom salt, and that the inert sulphate is thus formed. Hence, Epsom salt, or Glauber's salt, which is a sulphate of soda, becomes an antidote to the poisonous effects of sugar of lead, when taken soon after it.

VANADIUM.

Equivalent, 68. Symbol, V.

541. This new metal was discovered by Professor Sefström in 1830, mixed with some iron ore from Jaberg, in Sweden. Its name is from *vanadis*, a Scandinavian deity.

In its properties, vanadium appears to be between chromium and uranium. It forms with oxygen, two oxides and one acid, called the *vandaic acid*, and combines with several other simple non-metallic elements. The metal, which can only be obtained by a complicated process, has a strong metallic luster, like silver, and is so brittle that it can hardly be touched without falling into powder. By combination with the proper substances, it forms *chlorides*, sulphurets, and phosphurets. Of its uses, nothing more seems to be known, than that it makes an excellent writing ink, in the form of vanadiate of ammonia, mixed with infusion of nut galls.

NEW METALS.

542. Within the last few years, at least seven new metals, or metallic oxides, have been discovered in various parts of the world. None of them have thus far proved of any use to the arts, or luxuries of life. We have, however, taken pains to obtain some account of each, which is here inserted.

What are the uses of charcoal and lime in the reduction of lead? What compound of lead is said not to be poisonous? What antidote is mentioned to the poisonous effects of sugar of lead? How does Epsom salt act to neutralize the poisonous effects of the salts of lead? When was vanadium discovered? From whence is its name derived? What is the appearance of this metal? What are its uses?

ERBIUM AND TERBIUM.

543. These two metals were discovered by Mosander, while testing the ores of yttria. Information concerning them are quite limited. They do not appear to have been reduced to the metallic state, but exist only in the form of bases, with several acids, forming metallic salts, and also in the form of oxides.

ERBIUM.

Equivalent unknown. Symbol, E.

544. The oxide of erbium becomes of a deep brown color, when heated in the air, this color being lost when heated in hydrogen. The nitrate and sulphate of this metal are colorless.

TERBIUM.

Equivalent, 64. Symbol, Tb.

545. The oxide of this metal is colorless, but its salts are of a pale red. The nitrate does not deliquesce, but dries into a crystalline mass; the sulphate dries into a white powder.

DIDYMIUM.

Equivalent unknown. Symbol, D.

546. This metal, or rather its oxide, was discovered by Mosander, in an oxide of lanthanium. Very little is known of its properties, and nothing interesting.

NIOBIUM.

Equivalent unknown. Symbol, No.

547. This metal was detected by M. Rose, in an ore of columbium, found in Bavaria. It forms acids with oxygen, some of which have quite distinct properties; but little is known of these compounds.

PELOPIUM.

Equivalent unknown. Symbol, Pe.

548. This is another metal lately announced by Rose, and which he found in an ore of columbium. Like the last, it has thus far developed nothing interesting or useful.

RUTHERIUM.

Equivalent, 52. Symbol, Ru.

549. In preparing platinum from its ores, there remains a black powder, from which, as already noticed, several metals have been derived. From this residue is also obtained rutherium. It occurs in small porous masses, with a metallic luster, which oxidates on exposure to the air. It is infusible, even by the compound blow-pipe, and is insoluble in nitro-muriatic acid. It has been examined with much care, but no useful result has followed.

DONARIUM.

Equivalent unknown. Symbol, Do.

550. This metal was found by Bergmann, while testing certain ores found in Norway. It exists in the form of an oxide, and is reduced to the metallic state with much difficulty, and then exists in the form of a heavy powder, with metallic luster. It has not been of any use.

CHAPTER XX.

SALTS.

Note.—The symbols for the elements, with their binary combination, have been given, but those for the saline compounds are omitted, as useless for those for whom this book is intended. If, however, the pupil is desirous of giving such symbols, he has only to look back and ascertain those of the elements, and combine them for the compounds. As an example, we give the symbols for alum. $\mathrm{Al_2O_3+3SO_3+KO, SO_3+24\,Aq.}=262$.

551. The compound resulting from the union of any acid with an alkali, an earth, or a metallic oxide, in definite proportions, is called a *salt.*

The substance which combines with the acid to form the salt, is called the *base.* Thus, lime is the base of carbonate of lime. Any substance capable of combining with an acid to form a

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What is a salt? What is the base of a salt? What is a salifiable base? What is an acid? Are all acids sour to the taste? Do all acids contain oxygen? Do the alkalies contain oxygen?

salt, is called a *salifiable base.* The salifiable bases, therefore, are the alkalies, the earths, and metallic oxides.

Any compound, which is capable of uniting in definite proportions with a salifiable base, or which in solution is sour to the taste, or reddens vegetable blues, is an *acid.*

From this definition, it will be observed that acids are not necessarily sour to the taste. This, in many instances, arises from their insolubility, for an insoluble acid neither tastes sour, nor changes the color of vegetable blues. Other acids, which, though soluble, do not taste sour, and have little, if any action on colors, still have the property of neutralizing alkalies, and combining with salifiable bases in definite proportions; such is the prussic acid.

It was formerly supposed that all the acids contained oxygen, as the acidifying principle, but we have already had occasion to remark, that there are several known exceptions to this truth. Since the discovery of the compound nature of the alkalies, and the simple nature of chlorine, it is found that some compounds, in which oxygen exists as an element, are alkalies, and that others, containing no oxygen, are acids. Thus, the metal potassium, combined with oxygen, forms the alkali potassa, and chlorine, united to hydrogen, forms muriatic acid.

552. ALKALIES.—The *alkalies* are supposed to possess characters exactly opposite to those of the acids. Their tastes are pungent; they neutralize the acids, and change vegetable blue colors to green. There are, however, many compounds, capable of forming salts, and of neutralizing acids, which do not possess the latter characters. Thus magnesia, though a powerful neutralizing substance, excites no taste, and produces little change on vegetable colors. This want of action obviously depends on its insolubility in water.

Thus, a salifiable base does not necessarily contain sensible alkaline properties, but is any substance which forms a definite compound with acids, or which being soluble, has the alkaline taste, and changes vegetable blues to green. All the metallic oxides are salifiable bases.

553. OXIDES COMBINE.—In speaking of the solution of a metal in an acid, it must always be understood, that it is the

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Give an instance where oxygen, combined with a metal, forms an alkali. Give an instance in which chlorine and another simple substance united, form an acid. Why is magnesia tasteless? Are the metallic oxides salifiable bases? What change do the metals undergo before they are soluble in the acids? In what manner do the metals become oxides before they are dissolved? When zinc is thrown into diluted sulphuric acid, why does hydrogen escape?

oxide of the metal which is soluble, for no metal combines with an acid in its metallic state. The action of the acid is first to oxidate the metal; which it does, either by imparting to it a portion of its own oxygen, or by assisting it to obtain this principle from the water with which the acid is mixed. When copper dissolves in nitric acid, the metal is first oxidated at the expense of one proportion of the oxygen which the acid contains, and hence the fumes of nitrous gas which escape. But when zinc dissolves in dilute sulphuric acid, the metal is oxidated by the decomposition of the water, and then dissolved by the acid, and hence the escape of hydrogen during this process.

554. NUMBER OF SALTS.—It is said that at least 2000 salts are known, but this is a small number when compared with those which might be formed; for supposing each acid to be capable of forming a different compound with each salifiable base, and each base a distinct compound with every known acid, the salts would be numberless.

It may be supposed, from the variety of properties possessed by the acids, and the salifiable bases, with which they are known to combine, that the resulting compounds must present a great variety of different qualities, colors, and shapes, and in this we are not disappointed. Some of the salts are corrosive poisons, others are perfectly inactive on the animal system; some are used as medicines, others as paints, others in coloring, &c.

It is obvious that in this epitome of the science, only a limited number of these compounds can be described. These we shall arrange in groups, or classes, each group consisting of the same acid, united to different salifiable bases.

555. CRYSTALLIZATION.—Most of the salts are capable of being crystallized, that is, of forming dry solid figures of determinate shapes. During the act of crystallization, many of them combine chemically with a definite portion of water, which, therefore, is called the *water of crystallization.*

Some salts contain more than half their weight of water; this is the case with sulphate of soda, or Glauber's salt, which consists of 72 parts of the dry sulphate, and 90 parts of water. Other salts, as muriate of soda, or common salt, contain no water of crystallization. But these salts sometimes contain particles of water included mechanically within their substance,

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What number of salts are said to be known? On what principles are the salts thrown into groups? What is the water of crystallization? Do all the salts contain water of crystallization? Why does common salt decrepitate when heated?

and hence when heated they *decrepitate*, or fly in pieces, in consequence of the conversion of this water into steam. From this cause, common salt decrepitates violently when thrown on the fire.

Salts containing a large quantity of the water of crystallization, when heated, undergo the *aqueous fusion;* that is, they dissolve in the water they contain. *Anhydrous* salts, or such as are not chemically united with water, when heated undergo the *igneous* fusion. A salt is said to *effloresce*, when its water of crystallization evaporates, and it falls into a dry powder.

556. SOLUTION IN WATER.—Most of the salts are soluble in water; and with a few exceptions, the solvent power of this fluid is in proportion to its temperature. One of these exceptions is common salt, which is equally soluble in hot or cold water. Some of the salts require 500 or 600 times their own weight of water for solution. This is the case with carbonate of lime, and sulphate of lime. In a few instances, as in the sulphate of baryta, the salts are entirely insoluble in water. On the contrary, some of these compounds have such an affinity for water, as to enter into solution with that which they attract from the atmosphere. In these instances the salt is said to *deliquesce*. Muriate of lime is an example. It can not be kept in the solid state, unless closely excluded from the atmosphere.

557. DEFINITE PROPORTIONS.—All the salts are composed of definite proportions of their ingredients, and these ingredients are compounded of definite proportions of elementary bodies. Thus, sulphate of potash is composed of 40 parts of sulphuric acid, and 48 parts of potash. The acid is composed of 16 parts, or 1 atom of sulphur, and 24 parts, or 3 atoms of oxygen. Potash is composed of 40 parts, or 1 atom of potassium, and 8 parts, or 1 atom of oxygen.

558. DEFINITE NUMBERS.—Thus the salts are formed by the union of compound substances, and their equivalent numbers are the sums of the atomic weights of these substances. Thus, the equivalent number for the sulphate of potash is 88, being composed of the equivalents for sulphuric acid, 40, and the equivalent for potash, 48. How these latter numbers are ob-

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What is meant by aqueous fusion? What is meant by igneous fusion? When is a salt said to effloresce? What salt is equally soluble in cold or hot water? What salts require a large portion of water for solution? When is a salt said to deliquesce? What is said of the definite proportions of the ingredients and elements of the salts? What is the composition of sulphate of potash? How is the equivalent number for sulphate of potash obtained?

tained has just been explained; and indeed the whole of the above, so far as regards definite proportions, is only a recapitulation of what has already been stated more in detail, in its proper place; but is repeated here, because the doctrine of proportions applies especially to the composition of the class of compounds which we are now about to describe.

Some salts combine with each other and form compounds, which were formerly known under the name of *triple* salts.

But as, in these instances, only two bases combine with one acid, or two acids with one base, this kind of union is more properly indicated by the term *double* than triple; and this change being proposed by Berzelius, is now employed by recent writers.

In describing the salts, we shall follow the method already observed in respect to other compounds, and place the equivalent numbers at the head of each description.

CHAPTER XXI.

SULPHATES.

559. THE sulphates, when heated to redness with charcoal, are decomposed and changed into sulphurets. The oxygen, both of the oxide and the acid of which the salt is composed, unites with the carbon, forming carbonic acid, while the sulphur and metal combine to form the new compound, the sulphuret, or sulphide.

The sulphates in solution, are readily detected by muriate of baryta; the muriate being decomposed by the sulphuric acid, an insoluble sulphate of baryta is formed, which falls to the bottom of the vessel in the form of a white powder.

Several sulphates exist in nature, the most abundant of which are those of lime and baryta. The sulphate of lime is very abundant in some countries, and is employed as a manure, and in the arts, under the name of *gypsum*, or *plaster of Paris*.

What is meant by a double salt? How are the sulphates changed into sulphurets? In what manner does the charcoal and heat change sulphates to sulphurets? How does muriate of barytes show the presence of sulphuric acid?

SULPHATE OF POTASSA, 88.

1 eq. S. Acid, 40+1 eq. Potassa, 48.

VITRIOLATED TARTAR.

560. This salt is prepared by decomposing the carbonate of potash with sulphuric acid. Its crystals are in the form of six-sided prisms, terminating in six-sided pyramids. Its taste is saline and bitter. This salt suffers no change on exposure to the air. Its crystals contain no water of crystallization, and when thrown on the fire, decrepitate for the reason formerly explained. These crystals are soluble in 16 times their weight of water at 60 degrees.

The composition and equivalent number of this salt are seen above.

SULPHATE OF SODA, 72.

1 eq. S. Acid, 40+1 eq. Soda, 32.

GLAUBER'S SALT.

561. Sulphate of soda sometimes occurs as a native compound, and may be readily formed by saturating common carbonate of soda by dilute sulphuric acid. That sold by apothecaries is chiefly prepared from the contents of the retort after the distillation of muriatic acid.

This acid is obtained by distilling a mixture of common salt and sulphuric acid. The latter acid, combining with the soda of the muriate, the muriatic acid is evolved and sulphate of soda formed. This being purified, forms the Glauber's salt of commerce.

Sulphate of soda crystallizes in four and six-sided prisms. These crystals when exposed to the air, part with their water of crystallization, or *effloresce*, leaving the salt in the state of a dry powder. By this process the salt loses about half its weight.

According to the analysis of Berzelius, this salt contains 72 parts of the neutral sulphate, and 90 parts, or ten atoms of water.

The combining proportions, or equivalents, of the salts, refer only to the acids and bases which they contain, and not to their

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How is sulphate of potash formed? What is the composition and equivalent number of this salt? What is the composition of sulphate of soda? What is the common name of this salt? How is Glauber's salt prepared? What proportion of water does sulphate of soda contain? What is said of the definite quantity of the water of crystallization?

water of crystallization. It is found, however, that the water of crystallization is always combined in definite proportions, as well as the other ingredients. The combining number for water, as already explained, is 9, and in the present instance the doctrine of multiple proportions, by a whole number, is found to be precisely true, there being 10 atoms, or proportions, of water in this salt.

SULPHATE OF BARYTA, 118.

1 eq. S. Acid, 40+1 eq. Baryta, 78.

HEAVY SPAR.

562. The native sulphate of baryta is widely disseminated, though not often found in very large quantities at any one locality. It occurs both massive and in anhydrous crystals, which are generally flattened, or tabular. This substance is known under the name of *heavy spar*, having a specific gravity of nearly 4½, being the most ponderous of earthy minerals.

It is formed artificially by mixing the earth baryta with sulphuric acid.

The native sulphate is ground and fraudulently mixed with oxide of lead, as a paint.

This substance is sometimes employed to form the solar phosphori, a compound which shines in the dark, after having been exposed to the light of the sun.

It is prepared by first igniting the native sulphate, after which it is powdered and sifted. It is then mixed with mucilage of gum arabic, and formed into cylinders about the fourth of an inch in thickness. These being dried in the sun, are exposed to the heat of a wind furnace supplied with charcoal, for about one hour, and the fire suffered to burn out. The cylinders will be found among the ashes, retaining their original shapes, and must be preserved in a well stopped vial.

When this substance is exposed for a while to the sun, and then carried into the dark, it will emit so much light as to show the hour by a watch dial.

SULPHATE OF LIME, 68.

1 eq. S. Acid, 40+1 eq. Lime, 28.

GYPSUM. PLASTER OF PARIS.

563. This salt occurs abundantly as a natural production. It is composed of 68 parts of the pure sulphate, and 18 parts

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What is the composition and equivalent number of sulphate of baryta?

or two proportions of water. This salt is found crystallized in broad foliated plates, and also in compact masses. It is ground, and spread on certain kinds of land as a manure. In this state it is called ground plaster. The compact variety is called *alabaster*, and is cut, or turned into various ornamental articles, such as candlesticks, vases, and boxes. Some of these specimens are perfectly white, and being translucent, are among the most beautiful productions of the mineral kingdom. Other varieties of this mineral are colored with metallic oxides, and present the appearance of clouds, stripes, or spots of red, blue, or brown, interspersed, or alternating with each other.

Sulphate of lime is largely employed in forming the ornamental, or stucco work, for churches and houses. For this purpose it is first heated nearly to redness, or as the workmen term it, *boiled*, in order to expel the water of crystallization, and then ground in a mill. In this state it is a fine white powder, which being mixed with water and cast into moulds of various figures, form the ornamental work seen on the walls of churches and rooms. It also forms the moulds for stereotype plates.

After being mixed with the water, it must be immediately poured into the mould, for however thin the paste may be, it grows hard, or as the workmen call it, *sets*, in a few minutes, and no addition of water will make it thin as before. This is owing to the chemical combination which takes place between the anhydrous sulphate and the water, and by which the latter is made solid.

Sulphate of lime is soluble in about 500 parts of cold water, and as it exists abundantly in the earth, it is more frequently found dissolved in the water of wells and springs, than perhaps any other salt. When it exists in considerable quantity, it gives that quality to the water called *hardness*. Such water decomposes soap, by neutralizing its alkali, and therefore is not fit for washing.

SULPHATE OF MAGNESIA, 60.

1 eq. S. Acid, 40+1 eq. Magnesia, 20.

EPSOM SALT.

564. Epsom salt is sometimes obtained by evaporating the water of springs which contain it in solution, and sometimes it

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What is the common name of this salt? Is sulphate of baryta a native, or an artificial salt? How is solar phosphori prepared from sulphate of baryta? What curious property has the solar phosphorus? What is the composition of sulphate of lime? What quantity of water does this salt contain?

is made artificially, by first dissolving magnesian limestone in vinegar, which takes up the lime and leaves the magnesia. The magnesia is then purified by calcination, and afterward dissolved in dilute sulphuric acid, and crystallized by evaporation.

This salt appears in minute quadrangular shining crystals. These suffer little change when exposed to the air, undergo the watery fusion when heated, and are soluble in three-fourths of their own weight of boiling water. Its use, as a medicine, is well known.

Sulphate of magnesia is composed of 60 parts of the dry sulphate, and 63 parts, or 7 atoms, of water.

SULPHATE OF ALUMINA AND POTASSA, 262.

3 eq. Sulph. Alumina, 174 + 1 eq. Sulph. Potassa, 88.

ALUM.

565. Alum is a substance so well known, that its external appearance requires no description. Its taste is at once astringent and sweetish. It is soluble in about its own weight of boiling water. It crystallizes in octohedrons, or eight-sided figures, and, by peculiar management, these crystals may be obtained of great size and beauty. It is a double salt.

Sometimes alum is found ready formed in earth or friable rocks, and is extracted by collecting such earth into proper vessels, and pouring on water, which, passing through, dissolves the salt, and holds it in solution. The water being then evaporated, the alum shoots into crystals.

When the mineral which furnishes this salt is aluminous clay, mixed with sulphur and iron, which is more often the case, another method is taken. The mineral being exposed to heat, or merely to the action of the air, the sulphur attracts oxygen, and is converted into sulphuric acid, which then combines with the alumina, and forms a sulphate. If no potash be present in the earth, this is added, and the whole is treated by lixiviation, (that is, pouring on water until the salt is dissolved,) and the liquor afterward evaporated to obtain the alum.

What is the common name for sulphate of lime? What are the uses of sulphate of lime? What is the compact variety of this salt called? How is gypsum prepared to form stucco work? What chemical change is produced when the anhydrous sulphate is mixed with water? What is meant by anhydrous? What effect does sulphate of lime have on the water of wells? What is the composition of sulphate of magnesia? What is the common name of sulphate of magnesia? What is the use of this salt? How is sulphate of magnesia prepared? What is the common name of sulphate of alumina and potash? What is the composition of alum? What is the process by which alum is obtained?

Alum is used in medicine and in the arts. Its composition is stated at the head of this section. Alum is the base of a curious composition, called *Homberg's pyrophorus*, which ignites on exposure to the air. It is prepared in the following manner:

Reduce an ounce or two of alum to powder, and mix it with an equal weight of brown sugar. Put the mixture into an earthen dish, and keep it stirring over the fire until all the moisture is expelled. Then, having pulverized it finely, introduce the powder into a common vial, coated with a mixture of clay and sand. To the mouth of the vial, lute a small glass tube, or the stem of a tobacco-pipe, in order to allow the moisture and gases to escape. The vial, thus prepared, is set in a crucible, surrounded with sand, and the whole placed in a coal fire, and gradually heated to redness. At first, steam will issue from the tube, but afterward a gas, which, being set on fire, burns with a blue flame.

After the flame goes out, keep up the heat for about fifteen minutes, and then remove the crucible from the fire, and immediately stop the orifice of the tube with a piece of wet clay. When the vial is cool, pour its contents hastily into other vials, which are perfectly dry, and then cork them so as entirely to exclude the air.

This compound resembles powdered charcoal in appearance; but if a few grains be poured out, and exposed to the air, it soon glows with a red heat, and will set paper or wood on fire. If poured from the vial, at the distance of a few feet from the ground, it forms a shower of fire. When introduced into oxygen gas it spontaneously explodes, giving out intense heat and light, and affording a very brilliant experiment.

Small vials of this pyrophorus may be preserved for years, and may be made highly convenient, especially for itinerant smokers, and to those who are traveling through a wilderness.

The ignition of this substance is caused by its strong attraction for the oxygen of the atmosphere.

SULPHATE OF IRON.

1 eq. Sulph. Acid, 40+1 eq. Oxide Iron, 36.

COPPERAS. · GREEN VITRIOL.

566. This well known salt is the sulphate of the protoxide of iron, and may readily be formed by the action of dilute sul-

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What is the use of alum? How is Homberg's pyrophorus prepared?

phuric acid on metallic iron. The green vitriol of commerce is, however, manufactured directly from the sulphuret of iron, which nature furnishes in abundance. For this purpose, the ore, being raised from the earth, is exposed to the air, and occasionally sprinkled with water. By a natural process, the sulphur absorbs oxygen from the atmosphere, and is converted into sulphuric acid, which is retained by the water. The acid thus formed, combines with the iron, forming a sulphate of the metal, which appears, on the decomposition of the ore, in a greenish crust. The mass is then lixiviated, or washed by pouring water through it, by which the salt is dissolved, and afterward obtained in crystals by evaporating the water.

Sulphate of iron is of a greenish color, has an astringent metallic taste, and is soluble in three-fourths of its weight of boiling water. According to the analysis of Berzelius, it contains 76 parts, or 1 equivalent of the sulphate, and 63 parts, or 7 atoms of water.

Large quantities of this salt are employed in the arts, chiefly for coloring black, and making ink.

SULPHATE OF ZINC, 82.

1 eq. S. Acid, 40+1 eq. Ox. Zinc, 42.

WHITE VITRIOL.

567. When diluted sulphuric acid is poured on zinc, for the purpose of obtaining hydrogen, the residue, if allowed to stand, forms small white crystals. This is the sulphate of zinc. For the purpose of commerce it is made by roasting the native sulphuret of this metal, and then throwing it into water. The sulphate is formed by the decomposition of the sulphuret, on the same principle as above described for the manufacture of green vitriol, and being dissolved by the water, is obtained by evaporation.

Sulphate of zinc has a strongly styptic taste, is soluble in about two and a half parts of cold water, and reddens vegetable blue colors, though strictly a neutral salt.

This salt consists of 82 parts of the sulphate, and 7 atoms, or 63 parts of water.

It is employed in medicine, as a tonic and emetic.

What singular and curious property does this compound possess? For what useful purpose may this pyrophorus be employed? What is the composition of sulphate of iron? What is the common name of sulphate of iron? How is green vitriol manufactured on a large scale? Explain the chemical changes by which the sulphuret of iron is converted into copperas. What are the uses of sulphate of iron?

CHAPTER XXII.

NITRATES.

568. THE nitrates, when thrown on burning charcoal, deflagrate, or produce a vivid combustion of the charcoal. This is in consequence of the oxygen gas which they yield when heated, which unites with the combustible as it is expelled.

All the nitrates, without exception, are decomposed at high temperatures, and by heat alone. Some of them, as the nitrate of potash, or niter, yield oxygen gas in a state of considerable purity when heated, and hence are employed for the purpose of obtaining oxygen.

As all the nitrates deflagrate when thrown on burning charcoal, this simple test is sufficient to distinguish them from other salts. Another test of these salts, is their power of dissolving gold leaf, when mixed with muriatic acid.

The only native nitrates are those of potash, lime, soda, and magnesia.

NITRATE OF POTASH, 102.

2 eq. N. Acid, 54+1 eq. Potash, 48.

SALTPETER, OR NITER.

569. This salt may be prepared by saturating the common carbonate of potash with diluted nitric acid, and evaporating the solution until crystals are formed.

That used in commerce, and for the manufacture of gunpowder, is prepared by throwing into heaps, under cover, the remains of decayed vegetable and animal matter, found about old buildings. Heaps of such earth, when exposed to the air under sheds, gradually generate nitric acid, in consequence of the combination of the nitrogen, which is always contained in animal remains, with the oxygen of the atmosphere. The earth from such situations also contains lime, magnesia, and commonly considerable proportions of potash, from the ashes of burned wood. Thus there appears to be formed in these niter beds,

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Of what is sulphate of zinc composed? What is the common name of sulphate of zinc? How is the sulphate of zinc of commerce prepared? What proportion of water does this salt contain? What are the uses of white vitriol? Why do the nitrates deflagrate when thrown on burning charcoal? What gas do the nitrates yield when heated? How may the nitrates be readily distinguished from all other salts? What nitrates are found in the native state? What is the composition of nitrate of potash? What is the common name of nitrate of potash?

the nitrates of lime, potash, and magnesia. After the earth has remained in this situation for several months being now and then sprinkled with water, it is lixiviated, and to the solution of these salts there is added a quantity of potash, which decomposes the nitrates of lime and magnesia, thus leaving the nitrate of potash in solution. The niter is then crystallized by evaporating the water, and afterward further purified for use.

In the East Indies, this salt is formed spontaneously in the soil, and is found in small crystals on its surface. It is therefore obtained with great facility, nothing more being necessary than to lixiviate the earth and purify the niter.

Nitrate of potassa is a colorless salt, of a cool saline taste, which crystallizes in six-sided prisms. It contains no water of crystallization, but its crystals always contain more or less water mechanically retained in them. When heated, it undergoes the igneous fusion, and at a red heat is decomposed, first giving out oxygen, and afterward both oxygen and nitrogen, and if the heat be continued, there will remain only pure potassa.

In chemistry, this salt is employed in the manufacture of nitric and sulphuric acids, and for the purpose of obtaining oxygen gas. In the arts, it is chiefly used in the manufacture of gunpowder and fire-works.

570. **Gunpowder** is composed by weight, of six parts niter, one part sulphur, and one of charcoal. These ingredients being first finely powdered separately, are then mixed into the form of a paste, with water, and beaten together with a wooden pestle, until they become very intimately incorporated. This paste is then granulated, by passing it through sieves, and carefully dried in the sun, forming the grains of gunpowder.

571. **Fulminating powder** is made by mixing in a mortar three parts of niter finely powdered, two parts of carbonate of potash, and one part of sulphur. The whole being thoroughly mixed by grinding, forms the powder in question.

When a quantity of this mixture is placed on a shovel, and heated gradually, until the sulphur begins to inflame, it explodes, giving a loud and stunning report, and leaving the ears hardly in a state to hear any thing more for hours, or if the quantity be considerable, even for days. Not more than 15 or

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What is the process of preparing the niter of commerce? In what country is niter formed spontaneously? When niter is heated, what gases are expelled, and what substance remains in the fire? What are the uses of niter? What is the composition of gunpowder? How is fulminating powder prepared? How is this powder used?

20 grains of this powder should be exploded at once, unless in the open air.

572. NITRATE OF AMMONIA.—The mode of preparing this salt was described under the article *nitrous oxide*. This salt is composed of one proportion of nitric acid, 54, and one proportion of ammonia, 17=71. It also contains one proportion of water=9.

NITRATE OF SILVER, 164.

1 eq. Nitric Acid, 54+1 eq. Silver, 110.

LUNAR CAUSTIC.

573. When silver is thrown into nitric acid, the metal is dissolved, with a copious disengagement of red fumes, which consist of the deutoxide of nitrogen, formerly described.

The solution, if allowed to evaporate, will form large regular crystals, in the shape of flat rhombs. These, if the metal is unalloyed, are pure nitrate of silver. They contain no water of crystallization. They undergo the igneous fusion at a very moderate heat, and in this state, being cast into small cylindrical moulds, form the substance so well known, and so universally employed in surgery, and for other purposes, under the name of *lunar caustic.*

A solution of this salt in water, being applied to animal or vegetable substances, stains them, after exposure to light, of a permanent black color. The skin or hair may be made black in this manner, and there is no doubt but persons have colored their faces and hands with this substance, as preparatory to the commission of the worst of crimes. No washing, or any other means, will whiten the skin, once stained with this solution, until the scarf-skin itself wears off, or is removed, which requires several weeks. The solution itself is perfectly transparent, and in appearance can not be distinguished from pure water.

574. INDELIBLE INK is a solution of nitrate of silver in water, and is well known as the only substance in use, with which cotton and linen may be marked in a permanent manner.

Nitrate of silver, in solution, is decomposed by a variety of substances, having a stronger attraction for oxygen than the sil-

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When silver is thrown into nitric acid, what gas escapes? What is the composition of nitrate of silver? What is the common name of nitrate of silver? What is lunar caustic? What effect does a solution of nitrate of silver have on the skin, or hair? What is indelible ink? What substances are mentioned which decompose nitrate of silver?

ver has. By the action of such substances, the silver is revived, and appears in its metallic form. Thus, a stick of phosphorus placed in this solution, is soon covered with metallic silver; and if the solution be heated to the temperature of boiling water, with a little charcoal in it, the metal will be reduced, and may be obtained in the form of crystals.

The composition of the nitrate of silver is seen at the head of this section.

There are many other nitrates, but none of them are of sufficient use, or interest, to require a description in this book.

CHAPTER XXIII.

CHLORATES.

575. THE chlorates resemble the nitrates in many of their characters. These salts were formerly called *oxymuriates*. Most of them are decomposed at a red heat, with the evolution of pure oxygen gas, and are converted into metallic chlorides.

The pupil may find some difficulty in pointing out the distinction between the *chlorates* and *chlorides*. The chlorates are composed of chlorine united to oxygen, forming chloric acid, which acid, being combined with the metallic oxides, form chlorates. The chlorides are composed of uncombined chlorine, either united to the metals themselves, or their oxides. Thus, chloride of lime is composed of lime, or oxide of calcium, and chlorine. But chloride of calcium is composed of the two simple bodies, chlorine and the metal calcium, consequently contains no oxygen.

When the chlorates are decomposed by heat, as above stated, and converted into chlorides, the change is produced by the expulsion of the oxygen which the compound contained, and the subsequent union between the chlorine and the base of the alkali, or the metal itself. Thus, when chlorate of potassa is heated, its oxygen escapes, while the chlorine remains, and combines with the base of the alkali, forming chloride of potassium.

What were the chlorates formerly called? What is said of the decomposition of the chlorates by heat? What is the difference between the chlorates and the chlorides? What are the chemical changes by which the chlorates are converted into the chlorides?

In producing the chlorates, it is not necessary that the chloric acid should first be formed, and then combined with the salifiable base, since the same result is produced by merely passing the chlorine through a solution of the alkali. This will be explained under the chlorate of potassa.

The chlorates are all of them artificial compounds, none of them having been discovered in the native state. Most of them yield their oxygen to combustibles with such facility as to produce explosion. Thus, when chlorate of potash is rubbed in a mortar with phosphorus, or struck in contact with sulphur, violent detonations are produced.

576. GUN COTTON.—This is a recently invented explosive compound, which it was supposed by some would, for many uses, take the place of gunpowder. But the energy of its action, and the uncertainty with which it explodes, are such as to render it a dangerous agent, especially in the hands of the inexperienced. It is therefore, at present, employed rather as a curiosity than as an article of general utility.

577. MANUFACTURE.—Gun cotton is made by a very simple process, though manufacturers differ somewhat in the proportions of their materials. The following is said to be one of the best: Mix together equal proportions of nitric acid and of strong sulphuric acid, say an ounce and a half of each, and into this immerse one hundred grains of clean cotton fiber, for five minutes. Then remove the cotton, and wash it in cold water until every trace of the acid is removed. Having dried it in the sun, or by means of a gentle heat, not to exceed 120 degrees, the manufacture is finished.

Gun cotton thus prepared, has the appearance of the common article, tinged a little yellow; though, on trial, it will be found to have lost much of its strength.

It is a dangerous agent in young hands, and must always be used with caution, sometimes exploding when not expected, and with only the heat of boiling water. Its combustion is as instantaneous as the best gunpowder, and is attended by an immense volume of flame, leaving not a trace in the form of carbon, or ashes, behind.

When confined, it explodes with terrible energy, and may therefore ultimately become a cheap and efficient agent in the

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In producing the chlorates, is the chloric acid first formed, or is it only necessary to pass the chlorine through the alkaline solution? Do any of the chlorates occur in nature? What is said of the facility with which the chlorates yield their oxygen to combustibles? How is gun cotton made? What is the appearance of this article? What is said of its dangerous properties?

art of mining. Its power of propelling balls is said to be about eight times greater than the same weight of gunpowder.

578. **Detonating sugar.**—Prof. Sobrero, of Turin, has discovered that detonating sugar may be prepared thus: Pour on powdered loaf sugar a mixture of two parts, by volume, of sulphuric, and one of nitric acid. The sugar is at once converted into a viscid mass. On adding about 20 times as much water as there was acid, the mass is converted into a white substance, which is diffusible in the acid mixture, is insoluble in water, but is quite soluble in alcohol and sulphuric ether. In a moderate heat it melts and is decomposed, without detonation; but if suddenly heated to redness, it explodes like gunpowder. By a blow with a hammer it explodes, but feebly. It has not been applied to any useful purpose.

CHLORATE OF POTASH.

1 eq. Chloric Acid, 76+1 eq. Potash, 48.

OXYMURIATE OF POTASH.

579. The chlorate of potash is formed by passing chlorine gas through a solution of the pure caustic alkali in water.

The pure potash is readily prepared in the following manner: Make a solution of the carbonate of potash in its own weight of hot water, in an iron vessel, and add to this as much quicklime by weight, as there was potash, and let the mixture boil for about ten minutes. Then strain the solution through a linen cloth, and it will be fit for use.

The lime absorbs the carbonic acid from the potash, forming with it an insoluble compound, thus leaving the alkali in its pure, or caustic state.

The caustic potash being placed in a proper vessel, the chlorine is passed into it as long as any of the gas is absorbed.

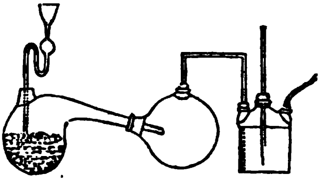
580. **Apparatus for chlorate of potash.**—The apparatus for this purpose is represented at Fig. 102.

The solution is contained in the three-necked bottle. The chlorine may be evolved by first introducing into the retort two ounces of finely powdered black oxide of manganese, and after every thing is arranged, as in the figure, pouring on this, through the safety tube, four ounces of muriatic acid, and then applying a gentle heat. When the solution is saturated, the gas will pass off by the bent tube into the open air.

What is said to be its force, compared with gunpowder? mposition of chlorate of potash? How is caustic potash prepared?

To obtain the salt, the solution is evaporated with a gentle heat, and on cooling, small shining crystals of chlorate of potash will be deposited. The first product only must be reserved for use, as the solution will afterward form crystals of muriate, instead of chlorate of potash.

FIG. 102.



Chlorate of Potash.

In the production of this salt, by the above process, the chloric acid is formed by the decomposition of the water, the oxygen of which unites with one portion of the chlorine to form the acid, while the hydrogen thus disengaged, unites with another portion of the chlorine, forming muriatic acid. Hence the solution as above intimated, contains both muriate and chlorate of potash.

When chlorate of potash is heated, it gives off oxygen gas nearly pure, and chloride of potassium remains.

581. Detonates with sulphur.—If two grains of this salt are mixed with one grain of sulphur, and the mixture is struck, or pressed suddenly, a loud detonation is produced. When struck in contact with powdered charcoal, a similar effect results. If a grain of the chlorate and half a grain of phosphorus be rubbed together in a mortar, very violent detonations will be the effect. In making this experiment, the hand should be covered with a glove, and the face protected by a mask, or averted, as the inflamed phosphorus is sometimes projected several feet by the explosion.

If a little of this salt be mixed with twice its weight of white sugar, and on the mixture a few drops of strong sulphuric acid be poured, a sudden and vehement inflammation will be produced.

These phenomena are owing to the facility with which the chlorate of potash parts with its oxygen to combustible substances.

582. Friction matches.—This salt forms the base of the matches, by which a light is instantly obtained. The chlorate

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What is the use of the lime in preparing caustic potash? Explain the process by which chlorate of potash is formed. How is the chloric acid formed by this process? Whence comes the muriate of potash which the solution contains? Mention some of the experiments which may be made with this salt and a combustible? How are the red matches prepared from this salt?

being finely pulverized by itself, is then mixed with twice its weight of white sugar, moistened so as to prevent explosion, and afterward made into a paste with mucilage of gum arabic. A little of this paste is fixed on the ends of brimstone matches, so that when it is inflamed, first the sulphur and then the wood is set on fire. These matches require only to be rubbed on a rough body, when they instantly burst into flame.

Attempts are said to have been made in France, on a large scale, to substitute the chlorate of potash for niter in the manufacture of gunpowder. But it was found that the workmen could not mix the ingredients, under any circumstances, without the greatest danger, and that in many instances explosions took place after the powder was prepared; the attempt was therefore abandoned. Attempts have also been made to use mixtures of this salt for percussion priming, but it was found that the chlorine acted so readily on the iron, as soon to injure the gun, and it was therefore laid aside, for the fulminating mercury, which is now generally used for this purpose.

CHAPTER XXIV.

PHOSPHATES.

583. THE phosphates of the metals are converted into phosphurets by heat and charcoal. Some of the alkaline and earthy phosphurets undergo a partial decomposition by the same means, while others are not changed. A number of phosphates are found in the native state, such as those of iron, lime, copper, and lead.

PHOSPHATE OF SODA, 64.

1 eq. Acid, 32 + 1 eq. Soda, 32.

584. This salt is prepared on a large scale in chemical manufactories, by neutralizing, with carbonate of soda, the superphosphate of lime, procured by the action of sulphuric acid on burned bones. The phosphate of lime, which the solution contains, is separated by filtration, and the liquid containing the

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What is said of the attempts made to substitute the chlorate of potash for niter, in the preparation of gunpowder? What are the phosphates which occur in the native state? What is the composition of phosphate of soda? How is the phosphate of soda prepared on a large scale? What is the use of phosphate of soda?

phosphate of soda is then evaporated until crystals of the salt are deposited.

The phosphate of soda is composed of one proportion of the acid, 32; one proportion of soda, 32; and twelve proportions of water, 108. It is employed in medicine, and in chemistry, as a reagent.

BORATES.

585. The borates are few in number, and being, most of them, of no use, are little known. They are distinguished by imparting a green color to the flame of alcohol, when dissolved in it. Any borate, being first digested in sulphuric acid, then evaporated to dryness, and the residue boiled in alcohol, produces this effect. Hence, this is the test for these salts.

BIBORATE OF SODA, 80.

2 eq. B. Acid, 48+1 eq. Soda, 32.

BORAX.

586. This is the only borate of any consequence, either in chemistry, or the arts. It occurs native in certain lakes in Persia and Thibet, which are said to be supplied from springs. The edges and shallow parts of these lakes are covered with a crust of borax, which being removed, another deposition is formed. It is imported into Europe and America in its rough or impure state, under the name of *Tincal*, and which being purified, forms the *refined borax* of commerce.

This salt is capable of being crystallized, in six-sided prisms, though more commonly seen in amorphous pieces.

It is soluble in six times its weight of boiling water. When exposed to heat, it enters into the watery fusion, and at the same time swells to several times its former bulk. When the water of crystallization is expelled, it passes silently into the igneous fusion, and forms a vitreous transparent globule, called *glass of borax*. Borax is used as a flux, by braziers and mineralogists, and is employed in medicine, in cases of sore mouth.

Besides the constituents of this salt placed at the head of this section, borax contains 8 atoms, or 72 parts of water of crystallization.

How are the borates distinguished? What is the composition of the biborate of soda? What is the common name of this salt? Where is borax found? What is glass of borax? What are the uses of borax?

FLUATES.

587. The nature of the fluates, owing to the uncertainty which exists concerning the base of the fluoric acid, are little known. These salts may, however, be readily identified by first reducing them to powder, and pouring on sulphuric acid, when, with the aid of a gentle heat, fluoric acid will be disengaged, and may be recognized by its property of corroding glass.

Several fluates are found in the native state, and it is from these only, or rather from one of them, the fluate of lime, that the fluoric acid is obtained. The *topaz* is a compound of fluoric acid, alumine, and silex. Its chemical name is *fluosilicate of alumina.*

FLUATE OF LIME, 38.

1 eq. F. Acid, 10+1 eq. Lime, 28.

DERBYSHIRE SPAR.

588. This salt is found in its native state, in many parts of the world. It is often seen as an article of luxury, cut into the form of vases, candlesticks, or boxes, under the name of *Derbyshire spar.* Its colors are purple, green, red, blue, and white, often mixed in the same specimen, and forming one of the most beautiful of mineral substances. This substance crystallizes in a great variety of forms, the cube being the most common.

Some varieties of this salt phosphoresce, when thrown upon hot iron, emitting light of various colors, as green, red, blue, &c.

When fluate of lime is exposed to the united action of sulphuric acid and heat, it is decomposed, the fluoric acid being liberated in the form of gas, while a sulphate of lime is formed. By this method the fluoric acid is obtained.

CARBONATES.

589. Some of the carbonates exist in great abundance in the native state. The carbonate of lime forms entire mountains. These salts may generally be distinguished from all others by their effervescence, when exposed to the action of the stronger acids. This is owing to the escape of carbonic acid during the decomposition of the salt. Thus, when sulphuric acid is poured

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What proportion of water does borax contain? How may the fluates be known? From what natural substance is the fluoric acid obtained? What is the chemical name of topaz? What is the composition, and what the combining number, of fluate of lime? What is the common name of fluate of lime? How is fluoric acid obtained? What carbonate forms entire mountains?

on carbonate of lime, the lime and acid combine, while the carbonic acid, being thus liberated, escapes through the solution, and occasions the effervescence.

The carbonates, with the exception of those of potash, soda, and ammonia, are very sparingly soluble in water. The carbonate of lime is entirely insoluble in pure water, but is slightly soluble in water containing carbonic acid.

Many carbonates of the metals, as well as of the earths, are found native. The carbonates of lime, of soda, barytes, strontian, magnesia, manganese, of iron, copper, and lead, are all native salts.

CARBONATE OF POTASH, 70.

1 eq. C. Acid, 22+1 eq. Potash, 48.

POTASH. PEARLASH.

590. The well known substance *pearlash*, is the potash of commerce deprived of its impurities, and saturated with carbonic acid. The potash of commerce is obtained by lixiviating the ashes of land plants, or common wood, and evaporating the solution to dryness. In this state it is of a dark reddish color, and when recently prepared, is exceedingly caustic to the taste and touch. By age its caustic property is gradually lost, in consequence of the absorption of carbonic acid from the atmosphere. Potash is chiefly employed in making soft soap and glass.

The *bicarbonate* of potash is prepared by transmitting a current of carbonic acid gas through a solution of the carbonate. This salt contains 44 parts of carbonic acid and 48 parts of potash, making its equivalent 92. It also contains 9 parts, or one proportion of water of crystallization. This is far milder, both to the touch and taste, than the carbonate. At a red heat it parts with one proportion of its acid, and is reduced to a carbonate.

This salt is in common use under the name of *sal æratis*. It is employed for culinary purposes; in many of the arts, and in medicine.

The bicarbonate of potash may be obtained in regular prismatic crystals by evaporating its solution gradually.

How may the carbonates be distinguished from all other salts? What occasions the effervescence when carbonate of lime is acted on by a strong acid? What carbonates are found native? What is the composition of carbonate of potash? What is the common name of carbonate of potash? How is potash obtained? What are the uses of potash? How is the bicarbonate of potash prepared? What is the common name of bicarbonate of potash?

CARBONATE OF SODA, 54.

1 eq. C. Acid, 22+1 eq. Soda, 32.

SODA.

591. The carbonate of soda is prepared by burning plants which grow in the sea, and lixiviating their ashes. The impure soda of commerce is known under the name of *barilla*, and is obtained by burning certain sea plants expressly for the purpose. An inferior kind is called *kelp*, and is prepared with less care and from different plants.

The carbonate of soda of commerce is prepared by dissolving barilla in water, filtering the solution, and then evaporating the water. If the evaporation is conducted slowly, the salt shoots into regular crystals. By continued gentle heat these crystals part with their water, and are rendered anhydrous without loss of carbonic acid. This salt dissolves in about its own weight of hot water.

Carbonate of soda is composed of one proportion of the acid, 22; one proportion of soda, 32, and 10 proportions, or 90 parts of water.

Hard soap is prepared entirely from soda. *Bicarbonate of soda* is made by transmitting carbonic acid through a solution of the carbonate in water. It may also be prepared by placing vessels containing the carbonate in the vats of a distillery, or brewery, where the process of fermentation is carried on. By either process the carbonate is made to absorb an additional proportion of the acid, and is thus converted into the bicarbonate.

This salt contains two proportions of the acid, 44; one proportion of soda, 32, and 9 parts of water.

The bicarbonate is in general use as a medicine, and forms the alkaline portion of soda powders. It also forms the basis of that agreeable beverage, soda-water.

MURIATES.

592. The muriates may be distinguished by the emission of muriatic acid fumes when tested with strong sulphuric acid. And also when in solution, by forming a white insoluble chloride, when tested with nitrate of silver. The muriates, when in a dry state, are chlorides.

How is the carbonate of soda prepared? What is the name of the impure soda of commerce? What is kelp? What is the composition of carbonate of soda? What kind of soap is made from soda? By what process is bicarbonate of soda made? How does the bicarbonate of soda differ from the carbonate of soda?

MURIATE OF AMMONIA, 54.

1 eq. M. Acid, 37+1 eq. Ammonia, 17.

SAL AMMONIAC.

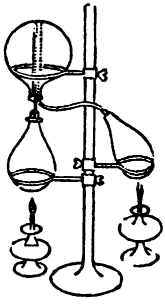
593. Sal ammoniac was formerly imported from the East, and particularly from Egypt; but has for many years been manufactured in large quantities, in several parts of Europe. Several processes are used at the different manufactories. The following is the method employed at a principal manufactory in Paris:

Two kilns are constructed of brick, in which are placed proper vessels for containing the materials employed. Into one of these vessels is placed a quantity of common salt, on which is poured sulphuric acid, and into the other are thrown animal matters, such as horns, bones, parings of hides, &c. On the application of heat there is extricated from one vessel, *muriatic acid gas*, and from the other, *ammonia*. These gases are conducted by flues into a chamber lined with lead, where they combine, and form solid muriate of ammonia, which incrusts the roof and sides of the room, and enters into solution with a stratum of water on the floor.

Muriate of ammonia, as seen above, is composed of muriatic acid and ammonia. Both these constituents exist in the state of a gas, but when combined they form the solid compound in question.

The elements of ammonia, (nitrogen and hydrogen,) exist in all animal substances, and the muriatic acid is a constituent of common salt. In the above process the ammonia is extricated by the heat, while the muriatic acid is evolved by the decomposition of the common salt.

FIG. 103.



Sal Ammonia.

This method of preparing sal ammoniac may be illustrated in the following manner, and affords a very instructive and satisfactory experiment.

Provide two flasks, each furnished with a tube, as represented at Fig. 103. Into one of these put a handful of common salt, and a little sulphuric acid, and into the other

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What are the uses of bicarbonate of soda? What is the composition of muriate of ammonia? What is the common name of muriate of ammonia? What is the process for making muriate of ammonia?

put equal parts of powdered quicklime and sal ammoniac ground together. Then invert over the ends of the tubes a tall bell glass, or a tubulated receiver, as seen in the figure, and apply a gentle heat to the bottom of each flask. The two gases will be disengaged, and combining, will form a white cloud within the receiver, which will gradually condense and cover its surface with solid sal ammoniac. If one of the gases be introduced into the receiver without the other, it will remain transparent and unseen until it meets the other, when a dense white cloud will instantly be formed.

In this experiment the ammonia is set free, in consequence of the decomposition of the muriate, by the quicklime, which combines with its muriatic acid.

The article used in smelling bottles, and called *volatile salts*, *hartshorn*, &c., is a carbonate of ammonia.

MURIATE OF BARYTES, 115.

2 eq. Muriatic Acid, 37+1 eq. Barytes, 78.

594. This salt is formed by saturating muriatic acid with carbonate of barytes. For this purpose, either the native or artificial carbonate may be employed.

Muriate of barytes crystallizes in four-sided tables, and contains nine parts, or one proportion of water. It is soluble in about two and a half times its weight of water; and is much employed as a reagent in chemistry.

HYDROSULPHURETS.

595. Sulphureted hydrogen is formed by the action of muriatic acid on sulphuret of antimony, or some other metallic sulphuret.

This gas is capable of forming salts with the alkalies, or alkaline earths, when passed into their aqueous solutions. It thus performs the office of an acid, and the compounds so formed are called *hydrosulphurets*.

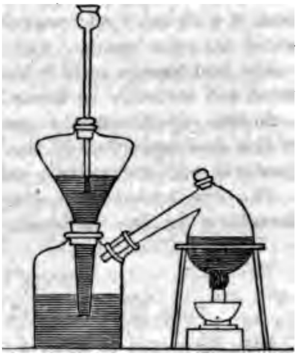
The hydrosulphurets are all of them easily decomposed, with the disengagement of sulphureted hydrogen; the fetid odor of which seldom leaves the experimenter in any doubt concerning the character of the compound.

How may the process of making the muriate of ammonia be illustrated by the apparatus represented at Fig. 103. What is the composition, and what the combining proportion, of muriate of barytes? How is the muriate of barytes prepared? What are the hydrosulphurets? How are the hydrosulphurets formed?

HYDROSULPHURET OF POTASH.

596. The best method of making this salt, or of impregnating water with any other gas, is by means of the apparatus represented by Fig. 104.

FIG. 104.



Hydrosulphuret of Potash.

The solution of pure potash in water, is placed in the lower vessel, while the materials for extricating the sulphureted hydrogen are contained in the retort. The influx of the sulphureted hydrogen into the lower vessel, drives the fluid into the upper one, the juncture between the two being made close by grinding. Thus, the fluid pressing on the gas, the absorption of the latter is greatly facilitated. In this manner soda water may be made, the tube in the upper vessel being convenient for the introduction of an additional quantity of soda, when required, or for a similar purpose when experimenting on other substances. These vessels being made of glass, the change in the height of the fluid, and consequently its degree of pressure on the gas, are made obvious.

This salt forms large transparent crystals, in the shape of six-sided prisms. Its taste is bitter, and it is soluble in water and alcohol.

COMBINATIONS OF HYDROGEN.

597. There are several combinations of hydrogen with various substances, and several names expressive of such compounds, some of which are new, and which, therefore, we will explain at this place.

HYDRACIDS.

598. The *hydracids* are combinations of hydrogen with certain bases, which compound performs the part of an acid in the formation of salts. These acids and their salts are therefore remarkable for the absence of oxygen, and the presence of hy-

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Explain Fig. 104, and describe in what manner the water presses on a gas generated in the retort, and force it into the upper vessel. What are the hydracids?

drogen. It was formerly supposed that oxygen was the universally acidifying principle, and hence its name, as already explained. But further investigations have shown that salts are formed without the presence of oxygen, hydrogen in one sense, being the substitute for oxygen. These compounds, therefore, are called *salts of the hydracids*, in order to distinguish them from the *salts of the oxyacids*, which contain oxygen, as the acidifying principle.

The substances with which hydrogen unites to form acids, are *chlorine*, *iodine*, *bromine*, *fluorine*, *selenium*, *sulphur*, and *cyanogen*. These acids, according to the nomenclature formerly explained, form severally, *hydrochloric*, *hydriodic*, *hydrobromic*, *hydrofluoric*, *hydroselenic*, *hydrosulphuric*, and *hydrocyanic* acids. The hydrocyanic is the *prussic* acid, the hydrochloric, the *muriatic*, and the hydrosulphuric, *sulphureted hydrogen* ; to the others, there are no old, or common names.

The *salts* which these acids form with alkaline or metallic bases, are *hydrochlorates*, *hydriodates*, *hydrobromates*, *hydrofluorates*, *hydroseleniates*, *hydrosulphates*, and *hydrocyanates*. These names of course indicate the constituents of the several compounds to which they apply.

Some of these salts are highly important and universally known, while others are worthy of notice only as chemical compounds. We shall here refer only to the former.

The *hydrochlorate of ammonia* is the muriate of ammonia, more commonly known under the name of *sal ammoniac*.

Hydrochlorate of soda is the muriate of soda, or common salt.

The *hydrocyanates*, or prussiates, have already been explained.

The *hydroferrocyanates* are salts which were formerly called *triple prussiates*. They are combinations of hydrogen, iron, and cyanogen, as the name indicates.

The term *hypo* is prefixed to a number of acids and salts, to denote the first degree of oxygenation. Hypo means *sub*, or *under*, and is employed in cases where bodies are capable of combining with more than two proportions of oxygen. The nomenclature of the acids of sulphur forms an example. These acids are four in number, depending on different degrees of oxygenation, and are termed 1, *hypo*sulphur*ous* acid; 2, sulphur*ous* acid; 3, *hypo*sulphur*ic* acid; 4, sulphur*ic* acid. When these several acids are combined with salifiable bases, the names of the salts thus formed are hyposulphites, sulphites, hyposulphates, and sulphates.

PART III.

CHAPTER XXV.

ORGANIC CHEMISTRY.

599. **Organic** chemistry comprehends the chemical history of all those different substances or elements, which form vegetable and animal bodies.

In many respects this department of chemistry differs very materially from that of the mineral kingdom. The analysis of inorganic bodies show, that each substance which differs materially from another substance, contains some principle peculiar to itself, or that the difference arises from the multiplied proportion of some one constituent, while the other remains the same. Numerous instances of both these cases will be found, on referring to the composition of various substances, and to such compounds as are formed by the union of different, but definite proportions of the same elements. Thus, sulphur, united with oxygen, and carbon united to the same element, form two compounds differing from each other in every respect, with the exception that they both combine with salifiable bases and form salts. And mercury, with one proportion of chlorine, forms a compound, which may be taken in large doses, and is in general use, as a medicine, while with another proportion of the same element, it becomes one of the most corrosive poisons known.

On the contrary, the elements of organized bodies are comparatively few in number, and although the different products, of which there is a great variety, must be composed of different proportions of these few elements, yet the resulting compounds of the same elements seldom present qualities differing widely from each other, like those of the mineral kingdom.

There is another wide difference between organic and inorganic chemistry. The latter presents us only with compounds

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What does the third part of this volume treat of? What does organic chemistry comprehend? In what respect does organic chemistry differ from mineral chemistry? What is said of the number of elements in organized bodies? What is the difference in the mode in which inorganic and organic substances are formed?

formed in consequence of affinity, or the attraction of the heterogeneous particles of matter for each other. But organic substances are formed by the action of peculiar organs, each organ being endowed with the power of producing different results from similar elements.

Thus, the several organs of the same tree produce wood, bark, flowers, fruit, gum, honey, &c., from the same elements; while the organs of secretion, and growth, in animals, produce bone, marrow, flesh, bile, fat, hair, nails, &c., from the same food.

In general the chemist finds little difficulty in decomposing and afterward imitating the products of the mineral kingdom, by again joining the same elements to each other.

But although he can decompose the products of organic action, and find the proportions of their elements, he never has been able to recompose or imitate these compounds. Thus, sugar and gum are found to be composed of hydrogen, oxygen, and carbon, and the exact proportions of these elements which they contain, are known; but no chemist has yet found the means of combining these elements, so as again to form sugar and gum.

Organic substances differ also from inorganic, in their tendency to decomposition. Thus, all animal and vegetable bodies, without exception, when exposed to the agencies of air and moisture, undergo spontaneous changes, their elements entering into new combinations, and forming new compounds to the entire destruction of the old ones. The compounds of the mineral kingdom, on the contrary, are generally permanent, many of them having probably not suffered the least change since their creation.

The changes which result from the decomposition of animal and vegetable substances, are often exceedingly complicated, and particularly when this is produced by heat, and in a close vessel. A compound, consisting of carbon, hydrogen, and oxygen, when thus treated, will produce water, carbonic acid, carbonic oxide, and carbureted hydrogen, and if the substance contains nitrogen, in addition to these, there will also be formed ammonia, and cyanogen.

What substances do the different organs of a tree form, from the same elements? What are the different substances mentioned, which the several organs of an animal produce from the same food? What is said of the power of the chemists to imitate inorganic and organic substances? What is the difference between inorganic and organic bodies with respect to the tendency to decomposition? What is said with respect to the complicated changes which organic bodies undergo, by decomposition?

CHAPTER XXVI.

VEGETABLE CHEMISTRY.

600. **Before** proceeding to describe particular substances, or the means by which the composition of vegetable products are ascertained, and to show the elements of which they are composed, we shall give a short account of the process of vegetation, and point out the chemical changes which take place during the growth of plants.

We have already stated, that the elements of which vegetables are composed are few in number, and that the great variety which we observe in plants, and their different parts, must therefore arise from the different proportions in which these few elements unite.

The constituents of vegetables are *carbon*, *hydrogen*, and *oxygen*, to which is occasionally added small proportions of *nitrogen*. The nitrogen, however, occurs only in such plants as emit the animal odor during their decomposition, as cabbage, and some of the mushrooms.

Notwithstanding the great variety which we observe in the texture, color, taste, smell, hardness, and other properties of different plants, as well as their several parts, such as flowers, seeds, and fruits, it is certain that their composition differ only in respect to different proportions of these elements.

601. Essential organs of plants.—The essential organs of plants, are the *root*, the *stem*, the *leaves*, the *flowers*, and the *seeds*. The *root* serves to attach the plant to the soil, and is one of its organs of nutriment.

The *stem*, which is usually erect, serves to elevate the leaves, the flower, and the fruit, from the ground, by which they are exposed to air and light. The *leaves* are the respiratory organs of the plant, and the *flower* performs the important office of giving rise and nourishment to the *seeds*, by which the plant is reproduced.

When a seed is exposed in a situation which favors its growth, it soon undergoes a change. It swells, grows soft,

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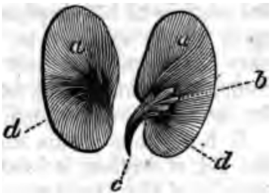
What are the elements, or constituents of which all vegetables are composed? How is the great variety under which vegetables appear accounted for, when their elements are so few in number? What are the essential organs of plants? What purpose do each of these organs serve? When a seed is placed in circumstances favorable to its growth, what changes does it undergo?

bursts its membrane, or shell, and at the same time, from being insipid and farinaceous, it becomes sweet and mucilaginous, thus becoming fit nourishment for the new pla[illegible] The stem and leaves are soon after elevated above the earth, in search of air, warmth, and light, while the root sinks into the ground in search of moisture and nourishment.

The seed, however various in form, consists essentially of the *cotyledon*, the *plumula*, and the *radicle*. The cotyledon contains the matter necessary for the early nourishment of the young plant. Sometimes this is single, sometimes double, and sometimes it is divided into lobes. The plumula is enveloped within the cotyledon, and is the part which produces the stem and leaves. The radicle shoots downward, and becomes the root.

FIG. 105.



Garden Bean.

The garden bean, having been a few days in the ground, shows all these parts in perfection, and is represented by Fig. 105. The cotyledons form the bulk of the seed, and are marked *a*, *a*. The plumula, *b*, and the radicle, *c*, are represented as beginning to shoot, while *d*, *d*, mark the membrane by which the whole has been inclosed.

602. GERMINATION OF SEEDS.—The circumstances necessary for healthy germination are, a temperature above the freezing point, and below 100 degrees; moisture in a certain proportion, depending on the kind of seed; and a proper access of air.

The joint operation of these several agents seem absolutely requisite; for seeds exposed to the action of air and moisture, at a temperature below 32 degrees, will not grow, though they may not be absolutely destroyed by the frost. Nor will seeds vegetate without the contact of some air, though both heat and moisture be present. This is shown by burying seeds deep in the ground, where they are known to lie in a torpid state for years, and in some instances, it is supposed, even for centuries. Thus, when alluvial soils are exposed to the sun, though taken from many feet below the surface, they afford grass from the

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What is said of the stem and roots? Of what does a seed essentially consist? What is the cotyledon? What is the plumula? What is the radicle? What are the circumstances necessary to healthy germination? Will seeds grow, when exposed to air and moisture, under 32 degrees? How is it shown that seeds will not vegetate without air?

seeds they already contain, and which had before remained torpid an unknown length of time, for want of the germinating power of oxygen.

This curious fact is confirmed by the experiment of Mr. Ray, who found that seeds exposed to heat and moisture, but confined in the exhausted receiver of an air-pump, showed no signs of germination.

603. GERMINATION REQUIRES OXYGEN.—Other experiments have proved that seeds will not grow under any circumstances, without the presence of oxygen. Healthy seeds, supplied with abundance of heat and moisture, but confined to an atmosphere of nitrogen, carbonic acid, or hydrogen, showed no signs of germination.

It appears, however, that only a very small quantity of oxygen, is required for this purpose, for Mr. Ray found that when the receiver of his air-pump was not completely exhausted, the seeds would sprout. In this respect several experimenters have been deceived, and in consequence of not producing a complete vacuum, have concluded that air was not necessary for the process of germination.

It being thus certain that seeds will not germinate without the aid of oxygen, it hardly need to be stated that the future growth of the plant must require the presence of the same principle.

The immediate sources from which plants draw their nourishment, has been a matter of doubt and controversy. It is certain, however, that they will not grow without the presence of heat, air, and moisture. It also seems necessary for their vigorous growth, that their roots should be placed in the earth, but whether this is requisite for their nourishment, or whether the ground serves merely to give them support, was a question long in dispute.

604. VAN HELMONT'S WILLOW.—Van Helmont planted a willow, which weighed five pounds, in a pot containing 200 pounds of earth. This he watered for the space of five years, and, at the end of that time, the tree was found to weigh 169¼ pounds, while the earth in which it had stood, being dried as at first, was found to have lost only two ounces. Here, then, was an increase of 164 pounds weight, and yet the food of the

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What was Mr. Ray's experiments on the growth of seeds? What gas is absolutely necessary to the growth of seeds? What are the agents necessary for the vigorous growth of a plant? What was the experiments of Van Helmont, and what was it supposed to decide?

plant had been water only. This experiment was supposed to settle all controversy, and to decide that the sole food of plants was water. But Mr. Boyle afterwards showed, that the water with which the tree was moistened, contained earth, from which the willow derives at least a part of the nourishment.

After a great variety of curious, and many elaborate experiments on this subject, it has been ascertained, that plants will germinate in pure water, and that the young plant, for a time, will grow with no other aliment; but that it finally grows sickly, and does not come to maturity and produce seed, without other nourishment.

A proof that plants do not thrive on water alone, is drawn from the well known fact, that soils become sterile by a long succession of crops, but are again made productive by the addition of new ingredients.

Nor does it appear that the simple earths, or clay, without some additional ingredients, are sufficient to support the growth of vegetables. On making an experiment, by planting seeds in pure silica, alumina, or magnesia, moistened with pure water, and exposed to proper degrees of heat, it was found that, although germination was effected, the young plants did not grow, until supplied with water, which contained vegetable or animal remains in solution.

It is for this reason, that earth, taken from a depth below the surface, never forms a productive soil. The soils best adapted to the growth of plants, always contain a proportion of vegetable mould, that is, the remains of decayed vegetables. This mould contains a quantity of matter which is soluble in water, and it is probable that the fertility of a soil depends, in a degree, on the quantity of soluble matter it contains, and that in this manner the aliment of plants is prepared for absorption by the roots.

The *sap*, which is prepared from the fluid absorbed by the roots, is constantly ascending up the vessels of the plant during its growth, until it arrives at the leaves. Here it undergoes a considerable change, the watery parts being thrown off by the perspiration of the leaves, while that which remains is converted into a peculiar juice, called the *true sap*, which, like the blood

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How did Mr. Boyle show that the willow did not live on water alone? What has been ascertained with respect to the growth of plants in pure water? What common fact, concerning soils, show that plants will not thrive on water alone? What is said of the growth of vegetables in the pure earths? Why does not the earth, taken from a considerable depth below the surface, form a productive soil? On what does the fertility of a soil appear to depend?

of animals, is afterward employed in forming the various substances found in plants.

The leaves of plants are not only their perspiratory organs, but they also serve the purpose of respiration, that is, they alternately absorb carbonic acid and emit oxygen at their surfaces.

Plants constantly throw off moisture from their surfaces, by perspiration, but the quantity is much larger during the day than during the night. Dr. Hales found that a cabbage transmitted, daily, a quantity of water nearly equal to half its weight. The office of transpiration is performed entirely by the under side of the leaf, and may be almost entirely stopped by spreading varnish on that surface.

605. PLANTS ABSORB CARBONIC ACID.—The fact that plants absorb carbonic acid was first observed by Dr. Priestley. Having suffered a sprig of mint to vegetate for ten days in a quantity of this gas, which would instantly extinguish a candle, he found, at the end of that time, that the candle was not extinguished by it as before, but that the flame continued for a while. Subsequent experiments have shown, that pure carbonic acid stops the growth of plants, but that a small quantity is absolutely necessary to healthful vegetation.

In Dr. Priestley's experiment, the sprig of mint could not have qualified the air in which it was confined, for the support of combustion, merely by the absorption of the carbonic acid. It must be inferred, therefore, from this experiment, that the plant not only absorbed carbonic acid, but that it gave out oxygen, or that it converted the carbonic acid into oxygen gas, and this inference has been confirmed by other experiments.

Plants, while growing in the light, absorb carbonic acid from the atmosphere, which they decompose; the oxygen, of which this acid is in part composed, being emitted, while the carbon is retained by the plant.

606. PLANTS EMIT OXYGEN.—If a growing plant, as a sprig of mint, be exposed to the sun, in a glass vessel filled with water, it constantly emits from its leaves small bubbles of air, which on examination are found to be oxygen gas. Now

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What changes does the sap undergo in the leaves? What is the true sap, and what its use? What office do the leaves perform besides that of perspiration? What proportion of water did Dr. Hales find a cabbage to transmit? What part of the leaf throws off moisture? What was Dr. Priestley's experiment with a sprig of mint and carbonic acid? In Dr. Priestley's experiment, what change did the mint produce on the carbonic acid? When a plant is exposed to the sun in a vessel of water, whence comes the carbonic acid which it decomposes? What two facts prove that plants emit oxygen in consequence of the decomposition of carbonic acid?

water, under ordinary circumstances, always contains a quantity of atmospheric air, and the atmosphere always contains a proportion of carbonic acid, and hence it may be inferred, that the water furnishes the air which the plant decomposes in this experiment; that this is the case, is proved directly by making the experiment with water, deprived of its air by the air-pump, or by boiling, when not a particle of oxygen is obtained.

That it is the carbonic acid which the plant decomposes, and from which the oxygen is derived, is proved by two facts. The first is, that vegetables are found not to emit oxygen, unless carbonic acid be present. The other is, that if the plant be confined in a mixture of carbonic acid and oxygen, the quantities of which are known, the proportion of oxygen will be increased, while that of the acid will be diminished.

From these facts we arrive at the wonderful conclusion, that plants absorb carbonic acid from the atmosphere, and that they retain the carbon for their own nourishment, but return the oxygen to purify the air. And from all that is known, it is most probable that a great proportion, if not all the carbon which wood contains, is derived from the atmosphere in this manner.

607. PLANTS ABSORB OXYGEN.—On the contrary, during the night, or when the light of the sun is withdrawn, plants absorb oxygen, and form with it carbonic acid, a part of which they emit, and a part is retained.

It appears from experiment, that vegetables not only cease to thrive, but that they actually die, if deprived of this nightly inspiration of oxygen. Thus, if a plant be confined during the day in a portion of carbonic acid, it decomposes a part of this gas, which is replaced by the emission of an equal volume of oxygen. But at night a part of this oxygen is absorbed and converted into carbonic acid, which is again emitted. Thus, ultimately, the plant decomposes all the carbonic acid, because it emits more oxygen during the day than it absorbs during the night. But if the oxygen which is formed during the day is withdrawn at evening, that is, if the plant has a new supply of pure carbonic acid every day, it soon droops, and dies for the want of its oxygen.

608. THE LEAVES OF PLANTS ABSORB WATER.—The leaves of plants absorb water, as well as carbonic acid and oxygen.

When plants decompose carbonic acid, what becomes of the carbon? From what source is it probable that plants derive most of their carbon? When do plants absorb oxygen from the atmosphere?

The great effect which the dew of night, or sprinkling with water, has on a drooping flower, is a proof that the leaves imbibe moisture.

Experiments also prove, that detached leaves often live for weeks, when swimming on the water, and that a plant which is dying for want of moisture at the root, will revive and grow, when a branch with its leaves is placed in a vessel of water.

It is most probable, therefore, that during dry seasons, and when there is a defect of moisture at the root, that the plant is in part sustained by the absorption of water from the air, and particularly from the dew as it falls at night.

609. PLANTS INCLINE TOWARD THE LIGHT.—In addition to heat, moisture, oxygen, and carbonic acid, healthy vegetation requires a certain quantity of *light*. It is well known that plants which grow in the dark are always nearly colorless, and that they appear weak and unhealthy. The disposition of plants to enjoy the light is expressed by their inclination toward it, when it is stronger in one direction than in another.

Thus, bean, or potato vines growing in a dark cellar, will always run toward the light, and if possible will creep out into the open air. And flowers, growing in pots placed near a window, will always lean toward the light, so that to keep them in a vertical position, the pots must often be turned. In thick forests, the trees grow tall for the same reason; they stretch upward to enjoy the light and heat of the sun.

Plants which grow in the dark contain more water, and less carbon, than those which grow in the sun. A plant which grew in the dark, on analysis of one of its branches, was found to contain only one ninetieth part of carbon; but on allowing the same plant to stand for thirty days in the sun, it was found to contain one twenty-fourth part of carbon.

This is readily accounted for, by the fact, that plants growing in the dark, emit no oxygen, but give out carbonic acid, and hence the defect of carbonaceous matter which they contain. This also accounts for the circumstance, that when a healthy plant is placed in the dark, it not only ceases to form carbon, but actually loses a part of that which it before contained, by the constant emission of carbonic acid.

How is it shown that plants droop and die, when deprived of oxygen? How is it shown that the leaves of plants absorb water? What agent does healthy vegetation require in addition to heat, oxygen, water, and carbonic acid? How do plants show their disposition to enjoy the light? Why do the trees in thick forests grow tall? What is the difference in composition between plants growing in the dark, and in the light? How is the small quantity of carbon contained in plants growing in the dark accounted for?

CHAPTER XXVII.

AGRICULTURAL CHEMISTRY.

610. **Observation.**—The analysis of soils, in order to detect what is considered injurious to any particular crop, and to remedy the defect by adding such ingredients as are wanting for general or peculiar cultivation, has of late years become so common, that the present state of science, in this respect, calls for at least a chapter on this subject, to the exclusion of less important matter. We, therefore, abridge the following from Liebig's Agricultural Chemistry, the most recent and important work on this subject.

611. **Chemical elements of a soil.**—The fertility of a soil is much influenced by its physical properties, such as its porosity, color, attraction for moisture, or state of disintegration. But independently of these conditions, the fertility depends upon the chemical constituents of which the soil is composed.

Experiment has shown that the alkalies, earths, and phosphates, which constitute the ashes of plants, are indispensable for their vigorous growth.

612. **Salts and acids.**—Plants require certain salts for their growth, the acids of which salts often exist in the soil, or are generated from nutriment derived from the atmosphere. If such materials do not exist within reach of the plants, their growth will be feeble, and the whole vegetation nearly or quite useless.

These salts do not, however, occur simultaneously in all plants; thus, in saline plants, soda is the only alkali found; in wheat and rye, lime and potash are constituents; and in other plants, magnesia and potash exist.

613. **Acids.**—The acids vary in a similar manner. Thus one species may contain phosphoric acid, in the form of phosphate of lime; another, phosphate of magnesia; a third, an alkali combined with silicic acid; and a fourth, an alkali in combination with a vegetable acid.

614. **Wheat.**—The most important and extensively cultivated crop in this country is *wheat*. This is best cultivated in a soil containing a good proportion of silicate of potash. That is, a soil consisting of sand, formed of quartz, feldspar, and mica, portions of which disintegrate by the action of the

weather, together with a mixture of decomposed vegetation. On such a soil, large fields of wheat may be produced every year for an indefinite time. As a manure for such soils, when required, it is said that wood ashes are among the best, since they contain both phosphate of lime and silicate of potash.

The *silicate of potash*, formed of silicic acid and potash, is a salt found in small quantities in plants, and also in many soils, in both of which it is detected by chemical analysis. The *phosphate of lime* is found in animal remains, especially in bones, of which they are chiefly composed.

615. SULPHUR IN PLANTS.—Most culinary vegetables contain sulphur in greater or less proportions. What are called by botanists *cruciferous* plants, as cabbage, mustard, and turnip, contain notable quantities of this element. Hence, as plants are found to thrive best on the materials of which they are at least, in part, composed, so it is a matter of experience, that all cruciform vegetables thrive best in soils containing sulphur. Gypsum, (which is sulphate of lime,) shavings of wood, refuse wool, or old woolen clothes, torn in pieces and decayed, each form excellent manure for all plants of the cruciferous family, as they all contain sulphur.

616. POTASH AND TOBACCO.—A most striking proof of the influence of potash upon vegetation, has been furnished by the investigations of the "*Administration*" on the subject of tobacco, in Paris. For many years, accurate chemical tests of the ashes of various sorts of tobacco, have been executed by order of the above-named authority, and it has been found as the result, that the value of the tobacco stands in a certain relation to the quantity of potash contained in the ashes. By this means, the soils on which the several kinds of tobacco grew, could be distinguished; and it was further ascertained that certain kinds of American tobacco had their value increased, or diminished, in proportion to the potash they contained. Hence it would appear that wood ashes, as a manure, gives value to the tobacco crop.

617. INDIAN CORN.—There are certain plants, says Liebig, which contain either no potash, or a mere trace of it. Such are the poppy and Indian corn, (*Zea mays.*) For such plants, the potash in the soil is of no use.

618. ANALYSIS OF DIFFERENT SOILS.—Liebig has given the analysis of a great variety of soils, in different parts of the world, chiefly, however, in the several departments of Germany, and in Hungary and Bohemia. In North America, he has

favored us with only two examples, both in Ohio, and of course in fertile regions, but in what parts he does not define. They are as follows:

NORTH AMERICA.

619. Surface soil of alluvial land in Ohio, remarkable for its fertility. 100 parts consisted of

Silica and silicious sand, ...	79.538
Alumina, ...	7.306
Iron, peroxide and protoxide of, ...	5.824
Peroxide of manganese, ...	1.320
Lime, ...	0.619
Magnesia, ...	1.024
Potash, with silica, ...	0.200
Soda, ...	0.024
Phosphoric acid, lime, and oxide of iron, .	1.776
Sulphuric acid and lime, ...	0.122
Chlorine, ...	0.036
Humus, soluble in alkalies, ...	1.950
Nitrogenous organic matter, ...	0.236
Wax and resinous matter, ...	0.025
	100.000

Surface and subsoil in the vicinity of the Ohio river. This soil was also distinguished for its great fertility. The surface soil is marked A and the subsoil B.

	A.	B.
Silica, with silicious sand, fine, .	87.143	94.261
Alumina, ...	5.666	1.376
Peroxide and protoxide of iron, .	2.220	2.336
Peroxide of manganese, . . .	0.360	1.200
Lime, ...	0.564	0.243
Magnesia, ...	0.312	0.310
Potash, with silica, ...	0.120	0.240
Soda, ...	0.125	
Phosphoric acid, ...	0.060	a trace.
Sulphuric acid, ...	0.027	0.0[illegible]4
Chlorine, ...	0.036	a trace.
Humus, soluble in alkalies, . .	1.034	
Humus, ...	1.072	
Carbonate of lime, ...	0.080	
Nitrogenous, organic matter, .	1.011	
	100.000	100,000

620. HUMUS.—This substance, mentioned in the above analysis, Liebig defines to consist of woody fiber in a state of decay. It is, therefore, carbon and water.

The property of woody fiber is, by uniting with the oxygen of the atmosphere, to convert it into an equal portion of carbonic acid gas. This gas, it is well known, is the most important food for young plants, and hence it is, that vegetation is so rapid and vigorous among old decaying wood.

The leaves of plants absorb this acid from the atmosphere, and by the aid of light, heat, and moisture, they convert it into their own substance, the carbon becoming solid, while the oxygen remains to purify the air.

Humus does not nourish plants by being absorbed into their substance, but by furnishing carbonic acid, as above stated, which is not only taken up by their leaves, but by their roots also.

621. HOW CHARCOAL OPERATES.—Charcoal is not subject to decomposition by time, heat, and moisture, but remains for ages under all such influences combined, without the least change. Pieces of this substance have been found in the catacombs of Egypt, where they had remained unchanged for thousands of years. It therefore does not furnish, by decomposition, any nutriment to plants, and yet there is no doubt but charcoal is a good stimulant to vegetation. This is explained on the principle of its great absorbing powers for the gases, and particularly carbonic acid, which gas, as above stated, is converted into wood by growing plants.

622. EXPERIMENT.—If charcoal, in a vessel containing the roots of a plant, be placed where it can not absorb carbonic acid, it will droop and expire, in the same manner and time that it would if placed in a vacuum. This is a proof that plants growing in charcoal, are supported entirely by its absorbing powers.

623. NO MATURITY IN CHARCOAL.—Although plants will grow in charcoal, yet they never attain maturity, and ripen their seeds, without some additional nutriment, such as water containing some salt, as potash, or the liquid manure, from decaying vegetables.

What is said of salts and acids for the growth of plants? What soil is best for wheat? What plants contain sulphur? What is the best manure for tobacco? What is said of potash as a manure for Indian corn? What is humus? How does charcoal operate to support vegetation?

CHAPTER XXVIII.

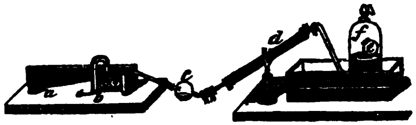
ANALYSIS OF VEGETABLES.

624. We know, as already stated at page 352, that the chief elements of vegetables are *carbon*, *oxygen*, and *hydrogen*; but that we may take the simplest case to illustrate the means of detecting these elements, we will suppose the subject of analysis consist only of *carbon* and *hydrogen*. In this case it is obvious that their entire combustion in oxygen gas, would afford nothing but carbonic acid and water. Now let us see how we shall come at the proportions of these. The quantity of carbonic acid being determined, either by weight or measure, the proportion of carbon could be inferred; and this ascertained and compared with the original weight of the substance to be analyzed, would give the proportion of hydrogen. Thus, suppose that 7 grains of the substance under analysis, yielded by combustion in oxygen, 22 grains of carbonic acid, then we should know that the quantity of carbon present was 6 grains, or 1 proportion of carbon united to 2 proportions of oxygen, 16 grains$=$22 grains of carbonic acid. The 1 grain of hydrogen of course combined with oxygen to form water, and as these unite in the proportions of 1 and 8, there would result 9 grains of water.

Suppose, in another instance, the weight of the compound to be analyzed was 15 grains, and that it was composed of hydrogen, oxygen, and carbon, as a piece of wood; and that on subjecting it to heat with oxide of copper, we obtained 22 grains of carbonic acid, and 9 grains of water, then the result would be by inference, that the wood contained carbon, 6, hydrogen, 1, and oxygen, 8$=$15, because, there being 9 grains of water, we infer by the law of definite proportions, hydrogen, 1, oxygen, 8$=$9, and there being 22 grains of carbonic acid, this, by the same law, is composed of carbon, 6, and oxygen, 16$=$22. Now, since there was only 15 grains of the wood, we infer that 1 proportion of the oxygen was derived from the wood, and 1 proportion from the oxide of copper.

The substance to be analyzed must first be reduced to powder, if capable, if not into small pieces, and mixed with about 100 times its weight of oxide of copper, then the mixture is to be dried in the vacuum of an air-pump, wherein is also a small vessel of sulphuric acid. The substance for analysis is first heated to about 212 degrees, or higher if it will bear it, and in this state set under the receiver, before containing the acid, and then the air exhausted. The acid by its affinity to water, abstracts all the moisture still retained by the substance in the dish.

FIG. 106.



Analysis of Vegetables.

The mixture to be analyzed being thus prepared, it is introduced into the tube of green glass, *a*, Fig. 106, which is open at the large end, and drawn out into a fine point at the other, to which is attached the small glass globe, *c*, communicating with the pipe, *d*, which contains chloride of calcium. From the tube, *d*, there passes a crooked tube, leading under the bell-glass, *f*, which stands in the mercury bath, *g*. The orifice of the tube, *a*, being closed by a piece of clay or otherwise, the tube is heated very gradually by burning charcoal, the screen, *b*, according to the directions of Prof. Mitscherlich, being necessary "for the purpose of preventing the heat from spreading too rapidly, lest the glass should become fused."

By means of the heat, the carbon and hydrogen of the substance to be analyzed, unite with the oxygen given out by the oxide of copper, so that a complete combustion goes on within the tube, and water and carbonic acid are composed. The water collects in the globe, *c*, and if any vapor passes, it is absorbed by the chloride of potash in the tube, *d*. That part of the apparatus being carefully weighed both before and after the process, the excess of weight must be due to the water. The carbonic acid passes along and escapes into the bell-glass, *f*, within which is the small glass globe, *e*, filled with moist caustic potash, into which the carbonic acid is directed, where it is instantly absorbed by the potash, and thus the additional weight of the globe and its contents will indicate the amount of carbonic acid generated during the process. Both the water and acid formed during the analysis, can be determined in the manner already pointed out, through the aid of definite proportion. If any nitrogen is evolved during the process, this will be retained under the bell-glass, and its quantity estimated. It will not be absorbed by the potash which takes up the carbonic acid. Or, perhaps, where the elements are complicated, one experiment had better be made for the nitrogen alone.

RECAPITULATION.

1. Vegetable substances are chiefly composed of *carbon*, *hydrogen*, and *oxygen*, but sometimes contain portions of *nitrogen*.

2. During the process of germination, the farinaceous substance of the seed becomes sweet, and affords nourishment to the young plant.

3. Healthy germination does not proceed without the combined presence of heat, water, and oxygen.

4. Seeds will not germinate in a vacuum, or in any gas which does not contain oxygen, though heat and moisture be present.

5. Plants receive nourishment from the air, as well as from the earth.

6. Plants nourished by pure water, and having access to the air, grow for a time, but do not produce seeds.

7. The nourishment which plants receive by the roots, is probably in a state of solution in water.

8. The sap undergoes a change in the leaves, where it parts with a portion of water, and is thus fitted to form the various substances found in vegetables.

9. In the day time, plants absorb carbonic acid, retain the carbon, and emit the oxygen.

10. In the night they absorb oxygen, and give out carbonic acid.

11. Plants do not live unless they are permitted to absorb oxygen during the night; nor will they live unless they absorb a portion of carbonic acid during the day.

12. Vegetation will continue for some time in either carbonic acid, or oxygen gas; because when confined in *carbonic acid*, plants emit a quantity of oxygen during the *day*, which they absorb at *night*; and when confined in *oxygen*, they give out a quantity of *carbonic acid* at *night*, which again serves them during the day.

13. Healthy vegetation absolutely requires the agency of light.

14. Plants which grow in the dark are white. They show

The student should be able to answer all the questions involved in this recapitulation.

their propensity to enjoy the light, by leaning, or creeping toward it.

15. Plants growing in the dark, do not absorb, and decompose, but emit carbonic acid, and hence they contain a deficiency of carbon.

CHAPTER XXIX.

VEGETABLE ACIDS.

625. THE vegetable acids are generally less liable to spontaneous decomposition than other vegetable products. They form salts when combined with the salifiable bases. Most of them are decomposed by hot nitric acid, being converted into carbonic acid and water. All of them suffer decomposition when exposed to a red heat. These acids are numerous, but a large proportion of them are of little consequence, and therefore we shall describe only the most useful.

ACETIC ACID, 50.

4 eq. Carbon, 24. 3 eq. Oxygen, 24. 2 eq. Hydrogen, 2.

VINEGAR.

626. The acetic acid, or vinegar, exists ready formed, in the sap of some plants, either in a free state, or combined with lime, or potash. It may be formed artificially either by the acetous fermentation, or by the destructive distillation of wood.

In the first case, it is made by exposing wine, cider, beer, or any other liquid capable of passing through the acetic fermentation, to the action of the air. This last condition is absolutely requisite, for no liquid will form vinegar if prevented from the access of air, that is, from the presence of oxygen. The liquid must also be exposed to certain degrees of temperature, for the acetic fermentation does not proceed when the thermometer is at 32 degrees, and but very slowly when it is near this point.

In this process, little or no gas is evolved, but on the contrary the oxygen of the atmosphere is absorbed, so that the liquid undergoes a slow oxidation.

What is said of the tendency of vegetable acids to decomposition? How may the vegetable acids be decomposed? What is the composition of acetic acid? What is the common name of acetic acid? Is vinegar ever found ready formed in plants? How may this acid be formed by art? What liquids form this acid by fermentation?

The vinegar obtained by the distillation of wood is called *pyroligneous acid*, that is, the acid of burned wood. When first made, it is very impure, and of a dark color, holding in solution carbon, soot, tar, creosote volatile oil, which gives it a strong smell of smoke. It is purified by a second distillation, and is largely employed for manufacturing purposes, and particularly in the preparation of white lead.

The acetic acid is distinguished from all other acids by its peculiar flavor, odor, and volatility. Its salts are called *acetates*. These salts are all of them decomposed at a red heat, or by the action of sulphuric acid.

ACETATE OF LEAD, 162.

1 eq. A. Acid, 50+1 eq. Oxide Lead, 112.

SUGAR OF LEAD.

627. This salt is prepared by dissolving either litharge, or white lead, in distilled vinegar. The solution is sweet to the taste, and hence its common name. It occurs in small shining crystals, which contain 27 parts, or 3 atoms of water. This salt is partially decomposed when abandoned to the action of the atmosphere. It parts with its water of crystallization, and absorbs carbonic acid from the atmosphere, thus being changed into a carbonate, or into white lead. We have stated in another place, that in the manufacture of white lead, the same change is effected; the lead being first dissolved by the acetic acid, and afterward changed into a carbonate by the action of the atmosphere.

The acetate of lead is largely employed in the process of coloring, and as a sedative and astringent in surgery.

ACETATE OF COPPER, 130.

1 eq. Acetic Acid, 50+1 eq. Oxide of Copper, 80.

VERDIGRIS.

628. This salt may be prepared by exposing metallic copper to the vapor of vinegar. The process appears to consist in the

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What conditions are necessary to the production of vinegar by fermentation? What gas is absorbed from the air by the forming vinegar? What is the vinegar from distilled water called? How is the acetic acid distinguished from all other acids? What is the composition of acetate of lead? What is the common name for acetate of lead? How is this salt prepared? In what manner is this salt decomposed when exposed to the air, and what new salt is formed? What are the uses of acetate of lead? What is the composition of acetate of copper? What is the common name of this salt? By what chemical process is this salt formed? How is verdigris made in the large way?

absorption of oxygen from the atmosphere by the metal, after which it is dissolved in the acetic acid.

Verdigris is manufactured largely in the south of France, by placing plates of copper between the refuse of grapes after the juice is pressed out, for the making of wine. The fluids which the grapes still contain, pass through the acetic fermentation, by exposure to the atmosphere, and after several weeks, the plates acquire a coat of the acetate, which being scraped off, they are again exposed to the same process. The acetate is afterward purified by solution, and crystallization.

OXALIC ACID, 36.

2 eq. Carbon, 12+3 eq. Oxygen, 24.

ACID OF SORREL.

629. The oxalic acid exists ready formed in several plants, and particularly in the *oxalis acetosella*, or *wood sorrel*, and also in common *sorrel*. It is readily prepared artificially, by digesting white sugar in five or six times its weight of nitric acid, and evaporating the solution to the consistence of syrup. On cooling, crystals of oxalic acid will be deposited; but they should be purified by solution in water, and again crystallized by evaporation.

Oxalic acid crystallizes in slender, flat prisms, which have an exceedingly sour taste, and which in solution combine with the salifiable bases, and form a class of salts called *oxalates*. These crystals contain half their weight of water of crystallization.

This acid is easily distinguished from all others, by the form of its crystals, and by its solution, giving, with lime water, a white precipitate, which is not dissolved by adding in excess the same acid. Oxalic acid is one of the most prompt and fatal poisons known, when taken in large doses. Fatal accidents have many times happened, in consequence of mistaking this acid for Epsom salts.

This acid is employed by calico printers, for the purpose of discharging certain colors. It is also used in families, for taking out spots of iron mould, and other stains.

The oxalates are none of them of much importance. The oxalates of potash, like the acid itself, is sold under the name of *essential salt of lemons*, for removing stains from linen.

What is the oxalic acid composed of? In what plants is this acid ready formed? How is this acid formed by art? What are the salts called, which the salifiable bases form with oxalic acid? How is this acid distinguished from others? What is said of its poisonous effects? What are the uses of oxalic acid?

TARTARIC ACID, 66

4 eq. Carbon, 24 + 5 eq. Oxygen, 40 + 2 eq. Hydrogen, 2.

TARTARIC ACID.

630. Cream of tartar is the purified *lees*, or deposits of wine casks. From cream of tartar the tartaric acid is produced, by mixing the former with chalk in fine powder, and throwing the mixture into boiling water, by which the cream of tartar, which is a tartrate of potash, is decomposed, and a tartrate of lime is formed. The tartrate of lime is then washed, and decomposed by dilute sulphuric acid, which, combining with the lime, sets the tartaric acid at liberty, where it remains in solution. This solution being evaporated, the tartaric acid is obtained in white crystals.

This acid is employed by calico printers, to discharge false prints, and by tallow chandlers, to whiten their goods. It is also used, when dissolved in a large quantity of water, as a cooling beverage in the hot season. When mixed with carbonate of soda in solution, it forms the effervescing draught called soda powder, of which large quantities are prepared and sold during the summer season.

The effervescence, the only property which makes this drink agreeable, is occasioned by the union of the tartaric acid with the soda, in consequence of which the carbonic acid is liberated, and in escaping through the water, causes the effervescence.

This acid is remarkable for its power of combining with two bases at the same time, and forming *double* salts. The most important of these salts is well known under the name of *tartar emetic.*

TARTRATE OF ANTIMONY AND POTASH, 354.

2 eq. Tartaric Acid, 132 + 2 eq. Protoxide of Antimony, 156.
1 eq. Potash, 48 + 2 eq. Water, 18.

TARTAR EMETIC.

631. This compound, so singular from the number of constituents it contains, is made by boiling the oxide of antimony called *crocus metallorum*, with tartrate of potash, or cream of tartar.

What is the tartaric acid composed of? What is the substance from which tartaric acid is obtained? By what process is this acid obtained? What are the uses of tartaric acid? What occasions the effervescence of soda powders? What is the chemical name of tartar emetic? What is the composition of tartar emetic? How is tartar emetic prepared?

This salt crystallizes in transparent prisms, which afterward grow white and opaque by exposure to the air. It is soluble in about fifteen parts of cold, and three parts of hot water.

When dissolved in water, the solution gradually undergoes spontaneous decomposition, and becomes inert as a medicine. This may be prevented by the addition of about one-third part alcohol to the aqueous solution. This salt is also decomposed by many reagents, as by all the stronger acids, and several of the alkalies and alkaline earths, and even by vegetable substances. Infusion of nutgalls causes with it a whitish precipitate, which is considered a compound of tannin and oxide of antimony. This compound is inert, and hence the decoction of chincona bark, as it contains tannin, has been given as an antidote to an over dose of tartar emetic.

CITRIC ACID, 58.

4 eq. Carbon, 24 + 4 eq. Oxygen, 32 + 2 eq. Hydrogen, 2.

SALT OF LEMONS.

632. This acid is obtained from the juice of lemons, by the same process as that described for tartaric acid. Finely powdered chalk is added to the juice, as long as any effervescence ensues. The citrate of lime thus formed, is insoluble in water, and sinks to the bottom of the vessel. This being washed, is digested in dilute sulphuric acid, by which an insoluble sulphate of lime is formed, while the citric acid, being thus set at liberty, remains in the solution, and on evaporation is obtained in crystals.

These crystals are large, transparent, and beautiful. They undergo no change by exposure to the air, are exceedingly sour to the taste, but when dissolved in a large proportion of water, make an agreeable drink, in consequence of retaining the flavor of the lemon.

This acid forms salts with the salifiable bases, but none of them are of importance. There is a variety of other vegetable acids, most of which are of no importance in any respect. Some of them have been analyzed, while the composition of others are unknown. We may, however, conclude, by analogy, that they are all composed of oxygen, carbon, and hydrogen, in different proportions.

What is said of the decomposition of aqueous solution of tartar emetic? How may this decomposition be prevented? Explain the principle on which chincona, or Peruvian bark, has been given as an antidote to tartar emetic.

CHAPTER XXX.

INGREDIENTS OF PLANTS.

633. The *ingredients* of plants are distinct substances, formed by their secreting organs, and separable from each other without destructive distillation. They are separated by certain solvents, which have the power of dissolving some, but not others. Thus, water dissolves the gum but not the resin, while alcohol takes up the resin and leaves the gum. The solvents employed for these purposes are hot and cold water, ether, alcohol, and some of the acids.

The following are the principal ingredients, or what are called the *proximate principles* of plants, viz.:

Gum,
Sugar,
Starch,
Gluten,
Extractive,
Lignum,
Tannin,
Coloring matter,
Wax,
Fixed oil,
Volatile oil,
Camphor,
Resins,
Narcotine,
Bitumen,
Vegetable alkalies,
Vegetable acids.

We shall examine the properties of only the most important of these principles.

GUMS.

634. Gum-arabic may be taken as an example of pure gum. It dissolves in water, with which it forms a viscid solution, or *mucilage*, from which it may be obtained in its original state, by spontaneous evaporation. It is insoluble in alcohol, or ether, the former precipitating it from the watery solution in the form of white flakes. Gum is decomposed by sulphuric, and nitric acids. By the former, it is resolved into water, acetous acid, and charcoal; the latter produces with it oxalic and malic acid. When gum is submitted to destructive distillation, it affords water, carbonic acid, carbureted hydrogen, empyreumatic oil, and acetic acid.

What is citric acid composed of? What is the common name of this acid? How is citric acid obtained? What is the use of citric acid? What are the ingredients of plants? How are the ingredients of plants separated from each other? What are the principal ingredients, or proximate principles of plants? In what liquid is gum soluble. Into what substances is gum resolved by sulphuric acid? What are the products of gum, when submitted to destructive distillation?

SUGAR.

635. Sugar is chiefly obtained from the *sugar-cane*, a plant which grows in hot climates, and which yield it in a larger proportion than any other substance. It is also procured from the sugar-maple, by boiling down the sap which flows from incisions made in the tree; and from several roots, particularly the beet, from which large quantities are made in France.

In the manufacture of sugar from the cane, the first process consists in obtaining the juice, which is done by grinding and pressure. This is then evaporated by a gentle heat, during which a quantity of lime is added, partly for the purpose of neutralizing any free acid, and partly for the purpose of separating extractive matter, which unites with the lime, and forms a scum on the surface of the liquid. The evaporation is continued until it acquires the consistency of syrup, when it is transferred into wooden coolers, where a portion concretes into a crystalline mass, and in this state forms what is called *muscovado* or *raw* sugar. It is then placed in vessels with apertures in the bottom, where the more fluid parts drain off, and form the well known sweet syrup, *molasses.*

636. Refined sugar.—Raw sugar is refined by the following process: The sugar being dissolved in water, is mixed with the whites of eggs, or the serum of blood, and boiled. The albumen or serum is thus coagulated by the heat, and rising to the surface, brings with it such impurities as the sugar contained, which are removed by a skimmer. When the syrup is judged to be sufficiently clear, it is placed in smaller pans, and further concentrated by boiling, and then transferred into coolers, where it is agitated with wooden oars, until it appears thick and granulated. It now becomes white, and the crystals being broken by the agitation, facilitates the draining off of the colored matter which remains.

It is next placed in conical cups of earthenware, of the well known form called *sugar-loaf.* These having apertures at the bottom, a portion of molasses drains off, leaving the sugar much whiter than before. Lastly, a quantity of pipe clay is mixed with water to the consistency of cream, and poured on the loaves to the thickness of an inch. The water from this slowly

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What are the principal vegetables from which sugar is obtained? What is the process by which sugar is extracted from sugar-cane? Why is lime added to the juice of the cane when boiling? What is muscovado sugar? How is molasses obtained? How is raw sugar refined? What is the use of the albumen and serum used in this process? How is the sugar purified and whitened after it is placed in the conical cups?

percolates through the mass, and washes all remains of the coloring matter from the sugar. The loaves are then dried by heat, and put in papers for sale.

Refined sugar undergoes no change when exposed to the air, the dampness of raw sugar being caused by impurities.

Sugar is decomposed by the sulphuric and nitric acids. By analysis it is resolved into the usual constituents of vegetables, oxygen, carbon, and hydrogen.

STARCH.

637. Starch is an abundant principle in the vegetable kingdom, being one of the chief ingredients in most sorts of grain, and in many roots and seeds. The process for obtaining starch consists in diffusing the powdered grain or rasped root in pure cold water, by which the water is rendered white and turbid. After some hours, the grosser parts, which in wheat consists chiefly of gluten, are separated by straining, and the water which passes through, being placed in shallow vessels, deposits the starch, on standing. It is afterward washed and dried with a gentle heat.

If starch be boiled for a considerable time in water containing about a twelfth of its weight of sulphuric acid, it is converted into sugar. By careful analysis, it has been found that the only difference between the composition of starch and sugar, is, that the starch contains less hydrogen and oxygen, in proportion to the carbon, than sugar. How the acid acts to convert the starch into sugar, has not been satisfactorily explained. During the germination of seeds, a similar change is effected, the starch being in part converted into sugar.

The principal varieties of starch, are arrow-root, potato starch, sago, tapioca, cassava, salop, and the starch of wheat.

GLUTEN.

638. Gluten may be obtained from wheat flour, by forming it into a paste, with cold water, and continuing to wash the paste under the stream of the same fluid, as long as any thing is carried away. The starch being thus removed, a tough elastic substance, of a gray color, will remain, which is gluten.

What is said of the abundance of starch in the vegetable kingdom? What is the process for obtaining starch? How may starch be converted into sugar? What is the difference between the composition of starch and sugar? What are the principal varieties of starch? How may gluten be obtained? What is the appearance of gluten? What are some of the properties of gluten? Why is wheat flour said to be more nourishing than that of other grain?

This substance has no taste, and is insoluble in water, alcohol, or ether, but is soluble in alkalies and acids. If left to undergo the putrefactive fermentation, it emits an offensive odor, similar to animal substances, and from this circumstance it is apparent that it contains nitrogen, which indeed is proved by its yielding ammonia at a red heat.

Of all substances, wheat contains the greatest proportion of gluten, and it is owing to this circumstance, that wheat flour is more nourishing than that of other grain, gluten being the most nutritive of all vegetable substances. It is also owing to the presence of this substance in the flour, that the dough is tenacious, and the bread spongy, or light, the carbonic acid formed during the fermentation of the dough, being detained by the gluten, in consequence of which the whole mass is distended with bubbles of air.

Wheat contains from 18 to 24 per cent. of gluten, the remainder being principally starch.

EXTRACTIVE MATTER.

639. Most vegetables, when infused for a time in hot water, impart to it a brown color. When such solutions are evaporated, there remains a solid substance, of a brownish, or sometimes of a yellowish color, which is *extractive* matter.

Extracts are prepared by apothecaries, as a means of concentrating the virtues of plants for medicinal purposes. These extracts not only contain the proper extractive matter, but several foreign substances also, such as resin, coloring matter, oil, &c.

COLORING MATTER.

640. The coloring matter of vegetables is chiefly red, blue, green, yellow, or mixtures of these colors. Nearly all vegetable colors are discharged by the continued action of light, and without exception, they are all destroyed by the action of chlorine.

Acids and alkalies either destroy, or change the tints of vegetable colors.

The extraction of the coloring principles, and the transfer of them to different substances, constitutes the *art of dyeing*, an

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In what manner does the gluten in the dough produce the sponginess of the bread? What is extractive matter? What are the principal tints of the coloring matter of vegetables? What effect does light have on the coloring principle of vegetables? What are the effects of chlorine on these colors? What constitutes the art of dyeing? How are colors divided? What are substantive colors?

art which, in the succession of ages, has been carried to a high degree of perfection. This art has been practiced from the remotest antiquity; for the history of man informs us, that from the king on the throne, to the savage in the wilderness, all have ever been fond of decorating themselves in a variety of colors.

Colors have been divided into *substantive* and *adjective*. Substantive colors are such as do not require the intervention of any other substance to fix them permanently, their attraction for the cloth being sufficient for this purpose. Adjective colors require the intervention of some substance, which has an affinity both for the coloring matter, and the stuff to be dyed. This intervening substance is called a *mordant*. The mordant generally consists of a metallic salt dissolved in water, with which the cloth is impregnated, after which it is passed through the solution of coloring matter. The mordants most commonly employed are, *muriate of tin*, *sulphate of iron*, *acetate of iron*, and *sulphate of alumine*.

Different mordants are used for different colors, and different kinds of cloth. Thus, *black* is made with sulphate of iron, nutgalls, and logwood. *Yellow*, with alum, fustic, and saffron; *red*, of cochineal, madder, red wood, or archil, with muriate of tin, or sulphate of alumine for a mordant. *Blue* is made with indigo, &c.

TANNIN.

641. Tannin is the substance, by the absorption of which the skins of animals are converted into leather. This substance is contained abundantly in nutgalls, in the bark of many trees, particularly the oak, hemlock, and birch, and in most vegetable substances which are astringent to the taste.

Tannin may be obtained from any of these substances, by first bruising the article, and then digesting it in a small quantity of cold water, and afterward evaporating the water. This substance is of a yellowish brown color, extremely astringent to the taste, and soluble in water and diluted alcohol.

Tannin is distinguished by its affording an insoluble precipitate with isinglass, or any other animal jelly. It is on this principle that the art of tanning leather is founded. The hides are laid in vats, and between them there is thrown a layer of

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What are adjective colors? What are mordants in coloring? What are the principal substances used as mordants? What is tannin? What are the principal substances which contain tannin? How may tannin be obtained? How is tannin distinguished? On what principle is the tanning of leather founded?

of oak, or other bark, which contains tannin, in coarse powder. The tannin of the bark is first dissolved by the water, and afterward combines with the leather, by which it is rendered hard, and nearly impervious to water.

CHAPTER XXXI.

VEGETABLE OILS.

642. THE vegetable oils are of two kinds, *Fixed* and *Volatile*.

643. FIXED OILS.—These are found only in the seeds of plants, and chiefly in such as have two cotyledons, such as almonds, linseed, walnuts, and rape-seed. The oil of olives, however, is extracted from the pulp which surrounds the kernel.

The fixed oils are obtained by crushing or bruising the seed, and subsequent pressure. They are viscid, nearly insipid, and inodorous, and generally congeal at a temperature considerably higher than 32 degrees.

The fixed oils, with a few exceptions, undergo little other change, by exposure to the air, than that of growing more viscid, and acquiring a degree of rancidity. The latter change is owing to the absorption of oxygen, for rancid oils redden vegetable blues, showing that they contain a quantity of free acid.

The absorption of oxygen, by some of the fixed oils, and particularly by those of linseed and rape-seed, is sometimes so abundant and rapid, as to set fire to light porous substances on which they are spread.

These are called cases of *spontaneous combustion*, and in many instances, where these oils have been suffered, either by accident or otherwise, to come in contact with cotton wool or cotton cloth, destructive fires have been the consequence.

The alkalies combine with the fixed oils, and form soap. The composition of all these oils is, carbon, hydrogen, and oxygen.

What are the two kinds of vegetable oils? In what part of plants are the fixed oils found? How are the fixed oils obtained? What changes do these oils undergo by exposure to the air? What causes oils to become rancid? In what manner do these oils sometimes produce spontaneous combustion?

644. Volatile oils.—Plants and flowers owe their odor and flavor to volatile or *essential* oils. These oils are obtained by distilling the plants which contain them with water. The water prevents the plants from being burned. Both pass into the receiver from the still, where the oil is found either at the bottom, or on the surface, as its density is greater or less than that of water. Some fruits, however, yield essential oil by pressure; such are the orange, the lemon, and the bergamot, which contain it in vesicles in the rind of the fruit.

The odor of the essential oils is aromatic, and their taste penetrating. They consist of the odoriferous principle, by which plants are distinguished from each other in a concentrated state. These oils are soluble in alcohol, and very sparingly so in water. When dissolved in the former, they constitute *essences*, a great variety of which are manufactured, particularly in Paris, and sold as perfumes in most parts of the world.

All the volatile oils, when pure, pass away by evaporation. Hence, a good test of the purity of these oils is to let a drop fall on paper, and if any oily spot is left, after warming the paper, the essential oil has been adulterated by some fixed oil.

The essential oils burn with a clear, white light, and the only products of their combustion is water and carbonic acid. Hence, these oils are composed solely of carbon and hydrogen, the water and carbonic acid being formed by the absorption of oxygen to support the combustion.

On exposure to the atmosphere, they absorb oxygen, and in consequence become thick, and turn of a yellowish color. They are at length converted into solids resembling resins. Some of them during this process deposit crystals, when exposed to the agency of light.

Volatile oils do not unite readily with metallic oxides, and even with alkalies, no combination is readily effected. They dissolve sulphur in large quantities, forming the well known article called *balsam of sulphur*.

The following list contains the principal essential oils, with their colors and specific gravities annexed.

Oils of	Color.	Specific gravity.
Turpentine, ...	Colorless, ...	0.870
Lemons, ...	Pale yellow, ...	0.850
Anise, ...	" "	0.985
Juniper, ...	Greenish yellow, . . .	0.911
Chamomile, ...	Deep blue, ...	0.940
Caraway, ...	Pale yellow, ...	0.940

Oils of	Color.	Specific gravity.
Lavender,	Yellow,	0.870
Peppermint,	Greenish yellow,	0.920
Rosemary,	Colorless,	0.895.
Camphor,	White,	0.988
Mint,	Greenish,	0.975
Cinnamon,	Yellow,	1.035
Cloves,	Pale yellow,	1.061
Sassafras,	Red, or yellow,	1.094
Mustard,	Yellow,	1.038
Bitter Almonds,	Colorless,	1.043

In the above table, water, as formerly explained, is estimated at 1000. Most of these oils, it will be seen, are lighter than water, while a few, as oil of cloves, are heavier than that fluid. It is hardly necessary to describe the properties of these oils separately, as they are all in many respects quite similar. The odors of many of them are well known, and their tastes familiar to most persons who indulge in the use of candy. There are, however, a few of them which differ greatly from the rest of the class, and particularly in the power of refracting light.

BURNING FLUIDS.

645. The numerous accidents which have occurred in consequence of ignorance, or carelessness in the use of what are known under the name of "*burning fluids*," make it proper that some notice should be taken of these compounds in this epitome of chemistry.

There is some variety in the proportions of these compounds, but they all consist, essentially, of oil of turpentine and alcohol. Alcohol is composed chiefly of hydrogen, and when pure, burns with a pale bluish light, so entirely unfit for illumination, that a flame of the ordinary size of that of a lamp, will not show the hour by a watch at the distance of six inches. It burns without smoke, and hence is used as a spirit lamp. The oil of turpentine, (when pure, it is called *camphene*,) on the contrary, is composed chiefly of carbon, and burns with a white light, well fitted for illumination, but does not readily consume its own smoke, and hence deposits lamp black.

The alcohol, therefore, requires the turpentine to give it the power of illumination, and the turpentine requires the alcohol to make it burn freely, and without smoke. When the two are mixed the compound burns freely, without smoke, and with a most agreeable white light, well fitted for illumination.

This compound, as a hand light, has several advantages over oil; it burns with very simple apparatus, merely a tube and cotton wick; it requires no snuffing, and never smokes; and, perhaps, a still greater advantage is, that when spilled it does not soil the carpet, or dress; and, lastly, its light is much more brilliant than that produced by oil. But, on the contrary, while oil is always safe, the hundreds of accidents, and the number of agonizing deaths every year, caused by the burning fluid, are sufficient to show that its general use must always be attended with more or less hazard.

646. Explosive effects.—Common hydrogen, or the carbureted hydrogen, called *fire-damp*, or that used for gas-lights, will burn silently, or without explosion, when pure, but when either is mixed with oxygen, or atmospheric air, and fired, a violent detonation is the consequence. The same happens with respect to the vapor of burning fluid, which consists of hydrogen, or carbureted hydrogen; it never explodes unless mixed with oxygen, of which, however, the atmosphere contains a sufficient quantity for this purpose. When, therefore, the burning fluid in a lamp is nearly or quite exhausted, the space is filled with gaseous vapor, or fire-damp, which is instantly mixed with a portion of oxygen from the atmosphere, when the cover is removed: and now, the vessel is filled with an explosive mixture, which, if a blaze be brought near, will, of course, produce the effects of gunpowder, with more or less force, depending on the quantity, or perfection of the mixture.

The truth of these principles is illustrated by the frequent practice of attempting to replenish the lamp while it is burning. The cover is removed, the fluid poured in, which drives out the inflammable gas, and this, being lighter than the atmosphere, reaches the flame, and the whole instantly detonates, breaking the lamp, if of glass, and if of metal, throwing the fluid, which it sets on fire, in every direction.

But there is no need of supposing an explosive mixture, in order to produce the sad consequences which so often result from accidentally firing the burning fluid. If the mouth of the vessel is small, and the gas is set on fire within it, all the bad effects of an explosion will follow from the expansion of the contents by the heat, the vessel being broken, and the fluid set on fire and thrown in all directions.

647. Remedies.—To avoid the horrid results of these explosions, of which almost every weekly paper contains more or less cases, it is only required that persons having the charge of

burning fluid, or camphene lights, should observe the following rules:

1. Fill the lamps in the morning.

2. If a lamp requires to be filled in the evening, produce another light, and setting it at least two feet distant, put the caps on that to be filled, then remove the cover, and pour in the fluid.

3. See that there is no air-hole through the cover, by which the vapor within the lamp can gain admission to the flame.

4. See that the wicks fill the tubes so that the flame can not descend, in case the vapor by cold or otherwise, should be condensed.

5. Employ metallic lamps, furnished with wire gauze, on the principle of Davy's safety-lamp.

6. Understand that the wire gauze is no protector, if the glass lamp is broken while it is burning.

7. Never trust children, or careless persons, with the use of the burning fluid at any rate.

8. If you sell burning fluid, never draw it in the night, either for your customers or yourself.

648. Remark.—It is pretended that some compounds of this sort are not explosive, certain venders, or inventors, assuring the public, on their reputation for honesty, that *their* fluids can not be made to explode, and hence are perfectly safe. Now so far as this is true, the public ought certainly to thank such inventors, but it is believed that he who will make his own experiments on this subject, will find little or no difference in the explosive disposition of these compounds. If they will burn, their vapors will explode when mixed with air.

RESINS.

649. The resins are peculiar substances which exude from certain trees, or plants, or are contained in their juices. They commonly contain a portion of the essential oil of the plant. They are solid at common temperatures, and, when rubbed, show signs of electrical excitement. Their colors are yellow, reddish, and white, and most of them are translucent, or transparent.

The resins are soluble in alcohol, ether, and the essential oils, but are precipitated by water, in which they are entirely insoluble. They are dissolved, and at the same time decomposed,

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What are the resins? In what liquid are the resins soluble?

by the sulphuric acid, with evolution of sulphuric acid gas, and the deposition of charcoal.

The principal resins are, common resin, gum copal, lac, mastic, elemi, and dragon's blood. Common resin, called *rosin*, is what remains after the distillation of spirit of turpentine. The turpentine itself is obtained by making incisions in the fir tree, from which it exudes. This consists of resin, and the oil of turpentine, which are separated by distillation.

The uses of many of the resins are well known. Sealing-wax is made of lac, turpentine, and common resin. Copal and elemi, when dissolved in spirit of turpentine, or alcohol, form varnishes.

CHAPTER XXXII.

FERMENTATION.

650. **Fermentation** consists in a spontaneous exercise of chemical affinity, in a vegetable substance, or solution, in consequence of which its properties are materially or totally changed.

There are several kinds of fermentation, the names of which indicate the pruducts formed. These are, the *saccharine*, the *vinous*, the *acetic*, and the *putrefactive.*

The product of the first is *sugar ;* that of the second, *wine ;* that of the third, *vinegar ;* while the fourth results in the total decomposition of all vegetable matter, and the destruction of every useful product.

651. **Saccharine fermentation.**—The germination of seeds, and the malting of barley, are instances of the saccharine fermentation, the farinaceous being converted into saccharine matter, or sugar.

652. **Vinous fermentation.**—This, by the generality of mankind, is considered the most important of all fermentations, since, from the days of Noah and Alexander, to the present time, its product has been employed, either to heighten the pleasures, or as an antidote to the cares of this poor life.

Why are the resins precipitated by water? What are the names of the principal resins? In what manner is common resin, or rosin, obtained? What are the uses of some of the principal resins? What is fermentation? What are the different kinds of fermentation? What is the product of the saccharine fermentation? What is the product of the vinous?

Wine, as well as other intoxicating liquors, are produced only by the vinous fermentation; a process by which alcohol is formed. There are four conditions necessary to the success of this process. These are, the presence of water, sugar, and yeast, in mixture, and a temperature between 60 and 70 degrees. Or, instead of yeast and sugar, saccharine matter, and starch, or the sweet juices of fruits. These conditions, being united, there succeeds a brisk intestine motion, attended with the escape of carbonic acid gas in abundance, and at the same time the transparency of the fluid is diminished by the rising of opaque filaments, the whole being attended with an elevation of temperature. When these phenomena cease, the liquor is found to have lost its sweet, mucilaginous taste, and to have acquired some degree of acidity, with a brisk, penetrating flavor, and the power of producing intoxication.

653. Chemical changes in fermentation.—In respect to the chemical changes which take place during this process, it is found that after the fermentation, the sugar has entirely disappeared, and that it is replaced by a quantity of alcohol, none of which existed in the liquid before the process. Hence, sugar is converted into alcohol by the vinous fermentation. But the weight of the alcohol is never equal to the weight of sugar employed, by nearly one-half. This loss is accounted for by the escape of the carbon and oxygen of the sugar, in the form of carbonic acid. When the process is conducted in such a manner that the quantity of carbonic acid can be retained and weighed, it is found to correspond precisely with the loss of the alcohol; that is, the combined weight of the acid and alcohol are equal to that of the sugar. This may be made apparent thus: Sugar and alcohol are composed of

	Sugar.		Alcohol.
3 eq. of carbon,	18	2 eq. carbon,	12
3 “ “ hydrogen,	3	3 “ hydrogen,	3
3 “ “ oxygen,	24	1 “ oxygen,	8
	—		—
	45		23

This shows a loss of one proportion of carbon and two proportions of oxygen from the sugar, the alcohol containing only two parts of carbon and one of oxygen, while the sugar con-

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What is the product of the acetic? What are the results of the putrefactive fermentation? What changes do seeds and barley undergo by germination and malting? What are the four conditions necessary to induce the vinous fermentation? What gas escapes during this fermentation?

tained three of carbon and three of oxygen, the proportion of hydrogen being the same in both. The difference between the number for sugar and that for alcohol is, therefore, 22. Now, we have seen that carbonic acid is composed of one proportion, or atom, of carbon, 6, and two proportions, or atoms, of oxygen, 16, and these two numbers make the precise quantity of carbon and oxygen lost by the sugar, and which is not contained in the alcohol. Therefore, 45 parts of sugar produce, by fermentation, 23 parts of alcohol, which is found in the fermented liquor, and 22 parts of carbonic acid gas, which escape.

This investigation, while it affords a beautiful illustration of the doctrine of definite proportions, demonstrates that nothing is lost by a new arrangement, or interchange of elements.

It is believed, that the vinous fermentation never takes place without the presence of sugar, the elements of this ingredient, as shown above, furnishing by decomposition those of the alcohol. In cases where substances which contain no sugar are known to produce alcohol without the addition of this ingredient, the process is explained by the supposition that the starch which these substances contain, is converted into sugar by the saccharine fermentation. It is well known that potatoes, which contain little or no sugar, yield a large quantity of alcohol by fermentation. But potatoes contain a large proportion of starch, which entirely disappears during the process, being first converted into sugar, and then into alcohol.

ALCOHOL.

654. When a liquor which has passed through the vinous fermentation is distilled, there rises from it a fluid, having much more highly intoxicating powers than the fermented liquor from which it is obtained. This liquor has a sharp, penetrating taste, and retains the flavor and odor of the fermented liquor from which it is distilled. The fluid so obtained is *alcohol* mixed with water, and containing a portion of the essential oil peculiar to the vegetable which formed the fermentative solution, and which gives it a flavor. Thus, *brandy*, *rum*, and *whiskey*, have each a flavor of their own, which arises from this circumstance. These are called *spirituous* liquors.

What becomes of the sugar during the vinous fermentation? Is the weight of alcohol formed, equal to the weight of sugar employed? What becomes of the deficiency? What is the composition of sugar? What is the composition of alcohol? How does it appear that the loss from the sugar escapes in the form of carbonic acid? Does the vinous fermentation ever take place without the presence of sugar?

When a spirituous liquor is distilled, the alcohol is obtained in a state of much greater purity, the oil which it contained and most of the water being left in the retort, or still. In this state it is colorless, highly inflammable, produces cold by evaporation, and occasions a considerable augmentation of temperature by admixture with water.

Common alcohol contains a portion of water, and has a specific gravity of from 850 to 875, water being 1000. It may be further purified, or freed from water, by adding to it warm carbonate of potash, or muriate of lime, which combines with the water, and sinks to the bottom of the vessel, after which the alcohol may be poured off. Very pure alcohol may also be procured, by putting it into a bladder, which being suspended in a warm place, the water will slowly pass through the coats, while the pure alcohol is retained. The strongest alcohol which can be procured by either of these methods, has a specific gravity of 800, or 796, at the temperature of 60 degrees.

Pure alcohol has never been frozen, though exposed to the lowest temperature which art has ever produced. It is a powerful solvent, being capable of dissolving camphor, resins, soap, volatile oils, sugar, balsam, &c.

Pure alcohol has precisely the same properties from whatever substances it is obtained.

WINE.

655. *Wine*, properly so called, is exclusively derived from the fermented juice of the grape. The principal substances in this juice, are *sugar*, *gum*, *gluten*, and *bitartrate of potash*.

This liquid readily passes through the vinous fermentation, without any addition, or spontaneously, at temperatures between 60 and 80 degrees. After fermentation, the specific gravity of the liquid is diminished, its flavor is entirely changed, and it is found to contain exciting or intoxicating qualities, from the formation of alcohol, of which, before this process, it contained not the slightest trace. Alcohol is, therefore, the product, or creation, of the vinous fermentation.

A question naturally suggests itself here, says Prof. Brande, why the juice of the grape does not ferment in the fruit itself?

How is the process explained in cases where alcohol is formed by substances containing no sugar, as in potatoes? How are spirituous liquors obtained? What gives the peculiar flavor to distilled liquors, as brandy, rum, and whiskey? How is alcohol obtained? Do spirituous liquors yield pure alcohol on distillation? What is the specific gravity of common alcohol? How may pure alcohol be obtained? What is the specific gravity of the purest alcohol? What is said of the freezing of pure alcohol? What is said of the solvent powers of alcohol?

We know that ripe grapes, even when cut from the vine, exhibit no such tendency; they dry up, and shrivel, becoming *raisins*, but never fermenting, so long as the skin is entire. It was once supposed that this arose from the *gluten*, or *ferment* being in distinct vesicles, or cells, from those containing the *saccharine juices*, and that consequently fermentation could not ensue, till the fruit was mashed or broken, so as to mix these ingredients. But Gay Lussac found that when grapes were bruised, and carefully excluded from the air, no change ensued; but that even a momentary exposure of the pulp to the air, or oxygen gas, was enough to communicate to it the power of fermentation. This seems to arise from some recondite action of oxygen on the glutinous principle of the grape, by absorbing which, it acquires the properties belonging to *yeast*. It is curious how perfectly the exclusion of air is provided for by the natural texture of the grape skin, which does not allow its ingress in the smallest degree, though it admits of the transpiration of the aqueous vapor, as is shown by the desiccation of the fruit.

It is well known that there is a great variety of wines, which differ from each other in color, flavor, and strength, as well as in price. These differences depend on various circumstances, as purity, scarcity, fame, and real qualities, for in the latter respect there are certainly great and material differences. Some wines will not keep through the hot season, or in a hot climate, without such an addition of brandy as to injure, or spoil the original flavor and purity of the liquor; others have a fine flavor, and have naturally sufficient alcohol to preserve them in any, or all parts of the world.

ALCOHOL IN WINES.

656. All wines contain more or less alcohol, which, as above stated, is the product of the vinous fermentation. It was formerly denied, however, that the alcohol pre-existed in the wine, but that it was the product of distillation. Its elements, it was urged, did exist in the wine, but that they were brought together to form the alcohol by the heat of distillation, and then raised and separated from the wine by a continuance of the process. The inference of this belief has been, that he who drank wine, did not of course take any portion of alcohol, this depending on the fact, whether any had been added to the wine. But that wine, and in truth, all fermented liquors contain alcohol, and that this is the product of fermentation, is shown by the fact, that the juice of the grape, or other fermentative liquors,

contains no alcohol until after having passed through that process, and that after this, alcohol can be separated from it without distillation, or the use of heat in any way.

METHOD OF OBTAINING ALCOHOL WITHOUT DISTILLATION.

657. For this purpose, either wine, cider, or beer, may be selected, the experimenter being satisfied, that no alcohol has been added to the liquor, to be used in the experiment.

A glass tube, say half an inch in diameter, and two feet long, being procured, fill it about half full of the liquor to be tried. Then drop into the liquor pieces of carbonate of potash, which has previously been well dried by heat. Continue this until all the water has been taken up and incorporated with the alkali, when the alcohol will gradually rise to the upper portion of the tube, and stand in a distinct stratum on the other contents. By graduating the tube into 100 equal parts, by pasting on its outside a strip of paper thus divided, the percentage of the alcohol in different kinds of wine may at once be determined. It is difficult, however, if not impossible, to extract all the alcohol by this method, since the quantity of alkali necessary to absorb all the water, tends to thicken the liquid, and thus prevent some of the particles of alcohol from rising through it. While therefore, this method serves to show beyond all doubt, that the alcohol exists in the wine before distillation; yet when the experimenter designs to obtain the whole quantity of alcohol in any liquid, the only sure method is, after saturating the wine, or other beverage, with lime, or potash, to use a gentle heat; and a long necked glass retort, reaching a good distance into the receiver, is the best apparatus.

PROPORTIONS OF ALCOHOL IN DIFFERENT WINES.

658. The following table, from Brande's Manual of Chemistry, exhibits the proportion of alcohol, specific quantity of 0.825, at 60 degrees, by measure, existing in 100 parts of the several kinds of wine and other liquors.

PER CENT. OF ALCOHOL BY MEASURE.

1. Lissa, ...	26.47
"	24.35
Average, . . .	25.41
2. Raisin wine, ...	26.40
" "	25.77
Raisin wine, ...	23.20
Average, . . .	25.12
3. Marsala, ...	26.03
"	25.05
Average, . . .	25.09

TABLE OF THE PROPORTIONS OF ALCOHOL—CONTINUED.

4.	Port,	25.83
	“	24.29
	“	23.71
	“	23.39
	“	22.30
	“	21.40
	“	19.00
	Average,	22.96
5.	Madeira,	24.42
	“	23.93
	“ (Sercial,)	21.40
	“	19.24
	Average,	22.27
6.	Currant wine,	20.55
7.	Sherry,	19.81
	“	19.83
	“	18.79
	“	18.25
	Average,	19.17
8.	Teneriffe,	19.79
9.	Colares,	19.75
10.	Lachryma Christia,	19.70
11.	Constantia, white,	19.75
12.	“ red,	18.92
13.	Lisbon,	18.94
14.	Malaga,	18.94
15.	Bucellas,	18.49
16.	Red Madeira,	22.30
	“ “	18.40
	Average,	20.35
17.	Cape Muschat,	18.25
18.	Cape Madeira,	22.94
	“ “	20.50
	“ “	18.11
	Average,	20.51
19.	Grape wine,	18.11
20.	Calcavella,	19.20
	“	18.10
	Average,	18.65
21.	Vidonia,	19.25
22.	Alba Flora,	17.26
23.	Malaga,	17.26
24.	White Hermitage,	17.43
25.	Rousillon,	19.00
	“	17.26
	Average,	18.13
26.	Claret,	17.11
	“	16.32
	“	14.08
	“	12.91
	Average,	15.10
27.	Zante,	17.05
28.	Malmsay Madeira,	16.40
29.	Lunel,	15.52
30.	Sheraaz,	15.52
31.	Syracuse,	15.28
32.	Santerne,	14.22
33.	Burgundy,	16.60
	“	15.22
	“	14.53
	“	11.95
	Average,	14.57
34.	Hock,	14.37
	“	13.00
	“ (old in casks,)	8.88
	Average,	12.08
35.	Nice,	14.63
36.	Barsac,	13.86
37.	Tent,	13.30
38.	Champagne, (still,)	13.80
	“ (sparkling,)	12.80
	“ (red,)	12.56
	“ “	11.37
	Average,	12.61
39.	Red Hermitage,	12.32
40.	Vin de Grave,	13.94
	“ “	12.80
	Average,	13.37
41.	Frontignac, (Rivesalte,)	12.79
42.	Cote Rotie,	12.32
43.	Gooseberry wine,	11.84
44.	Orange wine,	11.26
45.	Tokay,	9.88
46.	Elder wine,	8.09
47.	Cider, (highest average,)	9.87
	“ (lowest,)	5.21
48	Perry, (average,)	7.26
49.	Mead,	7.32
50.	Ale, (Burton,)	8.88
	“ (Edinburgh,)	6.20
	“ (Dorchester,)	5.56
	Average,	6.87

TABLE OF THE PROPORTIONS OF ALCOHOL—CONCLUDED.

51. Brown stout, ...	6.80	55. Rum, ...	53.68
52. London Porter, (average,)	4.20	56. Gin, ...	57.60
53. " (Small Beer,) .	1.28	57. Scotch Whiskey, . .	54.32
54. Brandy, ...	53.39	58. Irish " . .	53.90

"The wines," says Professor Brande, "employed in the experiments upon which the preceding table is founded, were selected with all possible caution as to purity and quality; a given measure of each, (saturated, when necessary, with lime, or potassa,) was carefully distilled nearly to dryness, and the bulk of the distilled product was exactly made equal to that of the original wine, by the addition of distilled water. After 24 hours, its specific gravity was determined, and thence the quantity of alcohol, by reference to *Gilpin's Tables.*"

ETHER.

659. The name *ether* was originally applied to a highly fragrant and volatile liquid, obtained by the distillation of alcohol with sulphuric acid. But it has been found that the same substance, when distilled with other acids, affords a liquid possessing in some respects similar properties, and therefore these compounds are now distinguished by prefixing the name of the acid employed.

660. SULPHURIC ETHER.—To make sulphuric ether, pour into a tubulated retort a certain quantity of alcohol by weight, and add, in small portions at a time, the same weight of strong sulphuric acid, allowing the mixture to cool after each addition. Then connect the retort with a receiver, and, by means of a lamp, make the mixture boil. The receiver must be kept cold by the application of ice, or wet cloths. The ether will pass over and be condensed in the receiver. The ether thus obtained, contains a portion of alcohol, and commonly a little sulphuric acid, from which it is purified by agitation with potash, and redistillation.

In respect to the chemical changes which take place between the alcohol and acid, to form the new product ether, it is found, on analysis, that the latter substance is composed of two proportions of olefiant gas, and one proportion of water. The number for olefiant gas being 14, and that for water being 9, the equivalent number for ether is 37.

Now, olefiant gas consists of 2 atoms of carbon, 12, and 2

How is ether obtained? What is the process of obtaining sulphuric ether? What is the composition of sulphuric ether?

atoms of hydrogen, 2=14, to which 1 atom of water, 9, being added, makes the composition of ether.

Alcohol is composed of, or contains the elements of, 1 atom of olefiant gas, and 1 atom of water, and therefore alcohol contains double the proportion of water that ether does. Now, if 1 proportion, or atom of water, be abstracted from two of alcohol, the exact proportions constituting ether will remain. Thus, the number for alcohol being 23, double this number is 46, from which one atom of water, 9, being taken, there remains 37, the number representing ether. It will be seen, on comparing these several numbers, that they exactly correspond with the constituents above named, and it is supposed that this is the precise mode in which sulphuric acid operates to convert alcohol into ether. In consequence of the affinity of sulphuric acid for water, it abstracts one atom of that fluid from the alcohol, and thus the elements of ether remain.

Sulphuric ether is a light, odorous, transparent fluid, of a hot and pungent taste. Its specific gravity, when most pure, is about 700, water being 1000; but that of the shops is 740, or 750, owing to the presence of alcohol. When exposed to the open air, it evaporates with great rapidity, and occasions an intense degree of cold. This is in consequence of the principle already explained, that when a substance passes from a denser to a rarer state, caloric is absorbed.

Ether is exceedingly combustible, and burns with a blue flame, the product of its combustion being water and carbonic acid.

Ether is employed as a medicine in nervous fevers, and as a solvent in the arts. When pure, or when that of the shops is agitated with water, and, after standing awhile, is poured off, it is a solvent of India rubber, one of the most insoluble of vegetable products.

661. NITROUS ETHER is prepared by distilling alcohol with nitric acid, in a manner similar to that described for sulphuric ether, to which its leading properties are similar. It is, however, still more volatile, and is subject to decomposition by keeping.

Explain the difference between alcohol and ether, and describe the change by which the former is converted into the latter. What is the specific gravity of ether when most pure? How does ether occasion an intense degree of cold? Why does the evaporation of ether occasion cold? What are the uses of sulphuric ether? How is nitrous ether procured? How does the nitrous differ from the sulphuric ether?

CHAPTER XXXIII.

VEGETABLE ALKALOIDS.

662. **The** vegetable alkalies, as they were formerly called, as potash and soda, are obtained by the destruction and incineration of the vegetables in which they exist. The bases of these, as we have seen, are metals, and have already been described by the names of *potassium* and *sodium*. The alkaloids, on the contrary, are obtained, not by use of fire, but by maceration in pure water.

The following is an outline of the method by which they are obtained. In the first place, the substance containing the alkaloid is digested in a large quantity of water, the purer the better, which dissolves the salt, the base of which is the alkali. On adding some salifiable base, such as potash, or ammonia, which has a strong affinity for the acid of the vegetable salt, in the watery solution, this salt is decomposed, its acid combining with the potash, or ammonia, and thus leaving the vegetable alkali in the solution. This alkali being insoluble in water, while the new salt formed by the acid of the vegetable, with the potash, or ammonia added, is soluble, the former is obtained by filtering the whole, by which the alkaloid is detained, while the water containing the solution of salts passes the filter.

The alkaloids are all composed of carbon, hydrogen, oxygen, and nitrogen, as ultimate principles; but in the state above described, they contain several impurities, such as oleaginous, resinous, or coloring matter, with which they are combined in the plant. To purify them from these, they are mixed with a little animal charcoal, which deprives them of color, and then dissolved in boiling alcohol, in which all the alkaloids are readily soluble. This solution is filtered while hot, and yields the pure alkaloid, in the solid form of fine crystals, either on cooling, or by evaporation.

The following list contains the principal alkaloids, together with the plants from which they are obtained. Their exact compositions we have not thought necessary to detail, their ultimate principles being, as stated above, various proportions of

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How do the oxides of potassium and sodium differ from the vegetable alkaloids? How are the vegetable alkaloids obtained? Give an outline of the process by which these substances are procured.

oxygen, *hydrogen*, *carbon*, and *nitrogen*. The properties of the most important of these will be described.

TABLE OF THE ALKALOIDS, WITH THE VEGETABLES FROM WHICH THEY ARE OBTAINED.

Alkaloids.	Plants.
Aconita,	Aconitum napellus.
Aricina,	A bark from Africa.
Atropia,	Atropa belladonna.
Brucia,	Strychnos nux vomica.
Cinchonia,	Cinchona lancifolia.
Codeia,	Opium.
Conia,	Conium maculatum.
Corydalia,	Corydalis tuberosa.
Cynapia,	Æthusa cynapium.
Datura,	Datura stramonium.
Delphia,	Delphinium staphisagria.
Digitalia,	Digitalis purpurea.
Emetia,	Cephaelis ipecacuanha.
Hyoscyamia,	Hyoscyamus niger.
Meconia,	Opium.
Morphia,	Opium.
Narcotina,	Opium.
Nicotina,	Nicotiana tobacum.
Picrotoxia,	Menispermum cocculus.
Quinia,	Cinchona cordifolia.
Sanguinaria,	Sanguinaria canadensis.
Solania,	Solanum nigrum.
Narceia,	Opium.
Thebaia,	Opium.
Veratria,	Veratrum sabadilla.

MORPHIA.

663. This alkaloid is the medicinal agent in opium, in which it exists with meconic and sulphuric acids, and also with narcotina, codeia, narceia, meconin, coloring matter, a fixed oil, and a little caoutchouc, or India rubber. In its pure state, morphia exists in the form of brilliant prismatic crystals, which are transparent and colorless. It is insoluble in cold, and nearly so in hot water; but in strong alcohol, especially when hot, it dissolves freely, and without difficulty.

Morphia is the narcotic principle in opium, but in the solid state, when pure, it appears, owing to its insolubility in water,

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What are the most important vegetable alkaloids? What is morphia? What are the ingredients in opium besides morphia? In what state does morphia exist in the opium? What is the process for obtaining morphia? What is the use of the magnesia in this process? What are the solvents of morphia? In what state is morphia used in medicine? Why is it not used in its pure state? What advantage has morphia over opium as a medicine?

to have little effect on the system; but, dissolved in alcohol, it acts with great energy.

There are several salts of morphia, as the *acetate*, *hydrochlorate*, and *sulphate*. The acetate, though till lately much employed in medicine, is less convenient for that purpose than the hydrochlorate, being variable in composition and strength.

NARCOTINA.

664. This is easily prepared by digesting the aqueous extract of opium in sulphuric ether, in which meconate of morphia and morphia are insoluble, but which takes up all the narcotina, and deposits it in regular crystals by evaporation. The stimulating action of opium is, in part, ascribed to narcotina, and it is said that pure morphia acts more agreeably and safely than when narcotina is mixed with it.

CINCHONIA.

665. This is obtained from the bark of several species of cinchonia, or *Peruvian bark*, by which name it is more commonly known. The process consists in taking up the soluble part of the bark with hot water, acidulated with hydrochloric acid. The solution, being concentrated by boiling, is then made alkaline by means of quicklime, when the cinchonia is precipitated, and is redissolved in alcohol, and obtained by evaporation.

Cinchonia, thus obtained, is in the form of small crystals, which are insoluble in cold water, but dissolves in 2500 times their weight of boiling water.

With acids it forms several salts, among which is the sulphate, composed of 1 eq. cinchonia, $156+1$ eq. sulphuric acid, $40=196$, eq. for sulphate cinchonia. It is employed in medicine.

QUINIA.

666. *Quinia*, or *quinine*, is also obtained from the bark of cinchonia, by a process similar to that described above. It is in the form of a white powder, hardly ever assuming the crys-

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How is narcotine obtained? Is narcotine soluble in water? What are the solvents of narcotine? What effects of opium are imputed to narcotine? What is said of the efficacy of cinchonia and quinia in the cure of fevers? What relation do cinchonia and quinia appear to bear to each other? In what species of bark do these alkalies exist? By what process are these substances obtained? What is the appearance of cinchonia? How do the alkaline properties of cinchonia appear? What salts does it form with acids? What is the appearance of quinia? What is the solvent of quinia? In what form is quinia employed in medicine? What is the appearance of sulphate of quinia, and what its composition?

talline form, though verging toward it when obtained by means of boiling alcohol. It is extensively employed in the practice of medicine, being a decided febrifuge, especially in cases of fever and ague.

The most important salt of quinia is the sulphate, which is very largely manufactured for medicinal purposes, and from its commercial value is often largely adulterated.

Sulphate of quinia is composed of 2 eq. quinia, $328+1$ eq. sulphuric acid, $40=368$.

STRYCHNIA.

667. This alkaloid is extracted from the *strychnos nux vomica*, a kind of nut, well known to apothecaries as a poison. It is prepared by treating powdered nux vomica with cold water, and afterward evaporating to the consistence of a syrup; alcohol is then added, which takes up the strychnia, from which it is precipitated by lime.

The alkaloid, thus obtained, is in the form of minute quadrangular prisms. It is nearly insoluble in cold water, but still excites an intolerable bitterness in the mouth. It is one of the most virulent poisons known, containing the essence of the deleterious properties of the nux vomica.

VERATRIA.

668. Veratria is obtained by a similar process to that above described for strychnia. It is contained in several plants of the hellebore tribe, known to botanists under the name of *veratrum*, one species of which is common in swampy places, well known by the appellation of *itch-root*. It acts with most disagreeable energy on the membrane of the nose, producing violent sneezing, though in very minute quantity. If taken, internally, it is a prompt and active poison.

EMETIA.

669. This is obtained from the root of ipecacuanha, by digestion in water, and the subsequent use of alcohol, as already described for the other alkaloids. It is a white, pulverulent substance, of a bitter, disagreeable taste, sparingly soluble in cold, but more freely in hot water. It is the cause of the emetic properties in the ipecacuanha, of which it contains about 16 per cent. The other alkaloids are extracted from the several plants named at the head of this article, by means similar to those

already described; but most of them being inert and useless, it is hardly necessary to go through their descriptions at this place.

CHAPTER XXXIV.

ANIMAL CHEMISTRY.

670. In relation to chemistry, the circumstances which distinguish animal from vegetable substances are, the large quantity of nitrogen which the former always contain, their strong tendency to putrefaction, and the offensive products which they exhale during decomposition.

Animal substances are essentially composed of carbon, hydrogen, oxygen, and nitrogen; and in addition to these, they sometimes contain sulphur, phosphorus, iron, and small quantities of saline matter.

671. Fibrin.—The lean parts of animals consist chiefly of *fibrin.* This may be separated and observed in its pure state, by removing the soluble parts of lean beef, cut into small pieces, by repeated washing, and digestion in cold water.

Fibrin thus obtained, is nearly white, and is insipid and inodorous. It readily passes into the putrefactive fermentation, but in thin pieces, suspended in a dry place, its fluid parts evaporate, and it becomes hard, brittle, and translucent.

Alcohol converts fibrin into a fatty substance, which is soluble in the same fluid, and in ether, but is precipitated by the addition of water. This substance is decomposed by all the strong acids, and is dissolved by caustic potash.

Fibrin is composed of 18 parts of carbon, 14 of hydrogen, 5 of oxygen, and 3 of nitrogen.

672. Albumen.—Albumen enters largely into the composition of animals. Their solid, as well as fluid parts, contain it in greater or less proportion. Liquid albumen is nearly pure in the whites of eggs. Its appearance, and many of its properties, in this state, are well known. It is coagulated, and con-

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In relation to chemistry, what are the circumstances which distinguish animal from vegetable substances? What is the essential composition of animal substances? What is fibrin? How may fibrin be obtained? What are the properties of fibrin? What is the composition of fibrin? Where is albumen found nearly in a pure state? By what agents is albumen coagulated? By what property is albumen distinguished from all other animal fluids? How does albumen clarify liquids?

verted into a soft solid, by heat, by alcohol, and by the stronger acids. The character of being coagulated by heat, distinguishes albumen from all other animal fluids. It is completely soluble in cold water, and it is said that when this fluid contains only $\frac{1}{1000}$ parth of albumen, it becomes opalescent by boiling. On this property is founded the clarifying effects of albumen. As it coagulates, by the heat of the water, it entangles any insoluble particles the fluid contains, and rises with them to the surface.

673. Gelatine.—This substance forms a proportion of all the solid parts of animals, and is particularly abundant in the skin, tendons, membranes, and bones. It is soluble in boiling water, and forms a bulky, semi-transparent, tremulous mass when cold. By evaporation, it becomes a solid, brittle, hard, and semi-transparent substance, known in commerce and the arts, under the name of *glue.* This is chiefly prepared from the cuttings of skins, and the ears and hoofs of animals. *Isinglass,* which is the purest variety of gelatine, is prepared from certain parts of fish, and especially the sturgeon. The gelatine called *calves' foot jelly* is prepared by boiling the feet of that animal in water.

Gelatine is precipitated by tannin. This is so delicate a test for gelatine, that it is said, an infusion of nut-galls, which contains a large quantity of tannin, will show the presence of gelatine when mixed with 5000 times its weight of water.

The three ingredients, fibrin, albumen, and gelatine, form the most bulky parts of all animals, that is, the flesh, tendons, cartilages, and skin.

OLEAGINOUS SUBSTANCES.

674. The *fat* of animals is very analogous, in its composition and proportions, to the fixed, vegetable oils, its ultimate principles being carbon, hydrogen, and nitrogen.

There is a considerable variety in the appearance and qualities of the fatty principle contained in different animals. The solid fat of land animals is called *tallow,* while the corresponding substances from fish, which is fluid at common temperatures, is called *oil.*

All these substances agree very nearly in respect to composi-

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In what parts of animals is gelatine most abundant? Under what name is dry gelatine known? What is isinglass? By what substance is gelatine precipitated from its solution? What parts of animals are formed by fibrin, albumen, and gelatine? What are the ultimate principles of animal fats? What difference is there between animal fats and animal oils?

tion, the principal difference being in respect to form and appearance. Their uses, for making soap, giving light, &c., are well known.

BLOOD.

675. The blood of animals obviously consists of two parts, called *serum* and *crassamentum.* In healthy blood, these two parts separate spontaneously on standing. The crassamentum coagulates, and forms a red, solid mass, while the serum surrounds it, in the form of a yellowish fluid.

676. SERUM.—The serum contains a small quantity of soda in a free state, and is 29 parts in 1000 heavier than water. It consists, in part, of albumen, and is coagulated by heat, acids, and alcohol. The crassamentum consists of two parts, the fibrin and the coloring matter. The fibrin does not differ, except in form, from that obtained from lean flesh, which has already been described.

The coloring matter of the blood consists of distinct particles, which in birds and cold-blooded animals, are elliptical in form, but in man, and other mammiferous animals, they are globular. These facts have been ascertained by means of the microscope. The globules are insoluble in the serum, but their color is dissolved by water, acids, and alcohol.

677. CRASSAMENTUM.—It has been supposed that the crassamentum contained a portion of iron, but recent analysis has shown that this metal does not belong to the crassamentum as a whole, but only to the coloring matter; for, when the fibrin is carefully separated from the coloring principle, it does not contain a trace of iron, while iron is always found in the red globules.

From the presence of iron in the globules, and its total absence in the other parts of the blood, it is inferred that the red color of the globules depend on the presence of this metal, though its quantity is found to be only half a grain to a hundred grains of the globules.

It is found that during the coagulation of blood, heat is evolved, and consequently its temperature is raised. This is owing to its passage from a rarer to a denser state, in consequence of which its capacity for caloric is diminished. We have had frequent occasions to refer to this principle. The increase

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In blood, what is the serum and what the crassamentum? What is serum composed of? What does crassamentum consist of? What does the coloring matter of blood consist of? On what metal does the coloring matter depend? What proportion of iron is contained in the red globules of the blood?

of temperature from this cause is, however, very slight, perhaps not more than two or three degrees; but its cooling is considerably retarded by the caloric thus evolved.

678. Causes of coagulation.—The blood presents several phenomena, which neither the principles of chemistry nor physiology have been able to explain. The cause of its coagulation, for instance, has never been satisfactorily accounted for. It does not arise from want of heat or motion, for if blood be drawn when the temperature of the air is equal to that of the animal from which it is taken, and then kept constantly in motion, its coagulation is not prevented, or even retarded. Indeed, neither moderate heat, nor cold, a vacuum, nor pressure, nor even dilution with water, seem to have any influence on the coagulation of the blood. On the contrary, its coagulation is prevented by certain causes, the effects of which could not be supposed to influence this circumstance. Thus, the blood of persons who have been destroyed by some kinds of poison, and by mental emotions, has been found uncoagulated, and in a fluid state. How causes so unlike should produce the same effects, or why either of them should affect the blood at all, are equally unknown.

RESPIRATION.

679. Respiration is the act of breathing, and consists in the alternate drawing into, and throwing out of the lungs, a quantity of atmospheric air. And it appears that this process, or an equivalent one, is necessary to support the lives of all animals.

The atmosphere, as formerly shown, is composed of 80 parts of nitrogen, and 20 parts of oxygen, and it is found by experiment, that no other gaseous compound can be substituted for respiration, nor can these proportions be varied without injury to its qualities.

The immediate effect of respiration is, to produce a change in the color of the blood as it passes through the lungs, thus indicating that it suffers some change in its properties at the same time.

What is said concerning the heat evolved by the coagulation of the blood? What is said concerning the cause of the blood's coagulation? What circumstances are said not to affect the coagulation of the blood? What circumstances are said to prevent the coagulation of the blood? What is respiration? What is the composition of the atmosphere? What effect does a change in the composition or proportion of the elements of the atmosphere produce on respiration? What is the immediate effect of respiration on the color of the blood? What is said of the necessity of respiration?

The necessity of respiration to all warm-blooded animals requires no proof; and the necessity that the blood should be brought into contact with the air inspired, is equally obvious from the organization of their lungs.

Such animals are provided with two kinds, or classes of blood-vessels, called *veins* and *arteries.*

The arteries, particularly the large ones, are deeply seated within the animal, and convey the blood to all parts of the living system. The veins, on the contrary, especially the small ones, are situated near the surface, and are destined to convey the blood back to the heart, which had been thrown out by the arteries.

But besides these two great systems of blood-vessels, there is another system called the *pulmonary*, which is destined expressly to convey the blood to the lungs, where it undergoes the change above mentioned, and then back again to the heart.

CIRCULATION OF THE BLOOD.

680. The entire circulation will now be readily understood. The blood being thrown to all parts of the body, is returned to the right side of the heart by the great system of veins. From the right side of the heart it is sent to the lungs, by the pulmonary artery, and being there changed into arterial blood, is returned by the pulmonary veins to the left side of the heart. From the left side of the heart, it is thrown to all parts of the body by the great system of arteries, to be returned to the right side by the veins, as before.

When venous blood, fresh drawn, is suffered to stand a few minutes in a confined portion of atmospheric air, it is found that the air loses a part of its oxygen, which is replaced by the same volume of carbonic acid gas, and at the same time the color of the blood, from being of a dark purple, becomes florid red. This is the same change of color which the blood undergoes in its passages through the lungs. The cause of the change in the lungs might, therefore, be inferred to be the absorption of oxygen by the blood, and the subsequent emission of carbonic acid.

That this change of color in venous blood, when out of the

What are the two kinds of blood-vessels called? Where are the veins and arteries situated with respect to each other? What is the use of the arteries? What part of the circulation do veins perform? What is the office of the pulmonary system? Explain the entire circulation. From which side of the heart do the great arteries convey the blood to all parts of the body? How is the blood conveyed from the right to the left side of the heart?

lungs, is owing to the contact of oxygen, is shown by the more immediate production of the same effect when oxygen is substituted for atmospheric air, and also by the fact that no change of color is produced when the oxygen is entirely excluded. Hence, the inevitable conclusion, that fresh drawn venous blood emits a quantity of carbon in consequence of its coming in contact with oxygen, and that its change of color is caused by this emission.

The same change thus proved to take place in the atmosphere, is constantly going on in the lungs. The venous blood, which, as above explained, is sent to the lungs through the pulmonary artery, is charged with carbon, to which it owes its dark color. The oxygen of the atmosphere, by inspiration, fills all the air vessels of the lungs, and is thus brought nearly into contact with the blood, being separated from it only by the thinnest membrane.

It appears that through this membrane, the oxygen of the atmosphere is absorbed, and having combined with a portion of the carbon of the blood, it is again emitted in the form of carbonic acid gas, and to this process is owing the change from venous to arterial blood.

681. Oxygen converted into carbonic acid.—In proof of this, experiment shows that when any living animal is confined in a portion of air containing a known quantity of oxygen gas, the oxygen gradually disappears, and is replaced by the same quantity of carbonic acid. In ordinary respiration, the air from our lungs always contains a portion of carbonic acid. This is proved by merely blowing into a glass vessel containing a solution of lime in water, or what is commonly called *lime-water*, when the clear water will instantly become turbid, because the carbonic acid from the lungs unites with the lime of the water, and forms an insoluble carbonate.

It does not appear that the oxygen is absorbed, and retained by the blood; for the absolute quantity of air, though many times respired by a confined animal, remains the same. This also proves that the nitrogen of the atmosphere is not absorbed. It is well known by experiment, that the conversion of oxygen gas into carbonic acid, does not in the least change its volume, but only adds to its weight. This accounts for the

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What effects do the contact of atmospheric air and venous blood produce on each? How is it proved that the change of color in the blood is produced by the oxygen of the air? What is the cause of the change of color in venous blood? To what is the dark color of venous blood owing?

reason why the volume of air is not changed by respiration, or by conversion into carbonic acid, provided no absorption takes place.

682. **Change from venous to arterial blood.**—Thus the change from venous to arterial blood, seems to be produced entirely by the loss of carbon, which the former suffers while passing through the lungs.

It appears also, from numerous experiments, that not only warm-blooded animals, but also fish, and cold-blooded reptiles of the lowest order, absolutely require the presence of oxygen in order to sustain life. Water, it has already been stated, always contains a portion of this gas in a free state, and although the quantity is small, it is sufficient to sustain the lives of its inhabitants. That fish, frogs, and other animals of this kind, can not sustain life without oxygen gas, is proved by the fact, that they die in a short time, if the water in which they are placed is covered with a film of oil, so that no oxygen is admitted. Frogs, though capable of suspending their respiration for a long time, die in less than an hour, if the small quantity of water in which they are confined is covered with oil. Aquatic insects and worms exhibit the same phenomena when treated in the same manner. In these cases, experiment has shown that oxygen is converted into carbonic acid, the effect being the same as that produced by the respiration of warm-blooded animals.

Indeed, the experiments of Spallanxani prove that animals produce this change by the action of their skin. Thus, serpents, lizards, and frogs, during their torpid state, and when their respiration is suspended, still require small portions of oxygen, which they constantly convert into carbonic acid by means of their skin, and it is probable, that in this manner, the blood of these animals parts with a little carbon.

CHAPTER XXXV.

ANIMAL HEAT.

683. During combustion there is an absorption of oxygen, and a subsequent emission of carbonic acid gas, and in the act

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What change does the blood undergo in the lungs? How is it proved that oxygen is converted into carbonic acid in the lungs? How is it proved that we emit carbonic acid at every expiration?

of respiration, oxygen disappears, and is replaced by the same acid gas. Combustion and respiration are therefore supported by the same principle, and yield the same product.

This analogy led Dr. Black to conclude that the changes which take place on the air, and on the blood in the lungs, was the cause of animal temperature; and several circumstances, relative to the structure of animals, and the quantity of oxygen they consume by respiration, seem to show that the heat of their blood depends, in a measure at least, on the quantity of this principle thus consumed. Animals having the power to maintain their temperatures above the media in which they live, are provided with capacious lungs, and consume large quantities of oxygen. Birds, the temperature of whose blood is higher than that of man and quadrupeds, have lungs still more capacious, according to their size, and consequently, most probably consume more vital air. On the contrary, fish, frogs, and other animals of this tribe, which consume only very minute portions of oxygen, do not sustain their temperature above the media in which they live.

684. TEMPERATURE RAISED BY OXYGEN.—It appears also, that the temperature of animals, when made to respire pure oxygen gas, is raised above the natural standard, but when the quantity of this gas consumed is small, the temperature of the animal falls, and the circulation of the blood is sluggish and languid.

From these considerations, it would appear that the heat of the animal is sustained by its respiration, and that its temperature is proportionate, in some degree, to the quantity of oxygen it consumes, or converts into carbonic acid.

Dr. Crawford, pursuing this idea, supposed that the carbonic acid discharged by the breath, being generated in the lungs, and accompanied with the loss of oxygen, extricated heat during its formation, and that the temperature of the animal might thus be explained. But as the heat of the lungs was found to be no greater than that of other internal parts, there must be some mode of accounting for its distribution to other parts of

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In respiration, is the oxygen absorbed and retained by the blood or not? How does it appear that neither the nitrogen nor the oxygen of the atmosphere is retained in the process of respiration? In what does the change from venous to arterial blood consist? What is said of the necessity of oxygen to support the lives of cold-blooded reptiles? How is it proved that fish and frogs require oxygen? What effect does the skin of torpid animals have upon oxygen? What analogy is there between combustion and respiration? What is said concerning the quantity of oxygen consumed by warm-blooded animals? What is said of the quantity of oxygen consumed by fish and frogs?

the system, otherwise this theory could not for a moment be supported. It is obvious that, in whatever manner this distribution is effected, the heat must be latent, or insensible; for, supposing it to be in a free state, the lungs or part where it is generated, would still be at a higher temperature than the parts to which it is distributed.

685. ARTERIAL BLOOD HAS THE GREATEST CAPACITY FOR HEAT.—Accordingly, on comparing the capacities of venous and arterial blood for heat, Dr. Crawford found, that arterial blood had the greatest capacity, and therefore, that at the same temperature, it contained a quantity of latent heat, which the venous blood did not. He therefore supposed that this latent heat was conveyed by the arterial blood, to all parts of the system, and as the arterial is gradually converted into venous blood, so the latent heat gradually became sensible, in all parts of the system, and that in this manner, animal temperature is maintained.

This beautiful theory was supposed to be founded on the true principles of chemistry and physiology, and being so received, it accounts very satisfactorily for animal temperature. But Dr. Davy has since shown that the principal fact on which it is founded, the difference of the capacities of venous and arterial blood for heat, is not true, but that in this respect there is little or no difference between the two kinds of blood.

If Dr. Davy has maintained the truth, it is obvious that Dr. Crawford's theory must fall to the ground.

Although the facts stated above, in respect to the capacity of the lungs, in warm-blooded animals, and the quantity of oxygen which they consume, when compared with cold-blooded animals, would seem to show almost beyond a doubt, that animal temperature is connected with the quantity of oxygen consumed, and the changes which the blood undergoes in the lungs; still, some physiologists deny the agency of either of these causes in producing such effects, and ascribe the evolution of animal heat entirely to the influence of the nervous system.

The foundation of this doctrine is an experiment of Mr. Brodie, who found that on keeping up an artificial respiration in

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Does it appear that there is any proportion between the heat of the animal and the quantity of oxygen it consumes by respiration? How did Dr. Crawford explain the cause of animal temperature? Suppose arterial blood to have a greater capacity for heat than venous blood, on what circumstance could animal temperature be explained? How did Dr. Davy show that Dr. Crawford's theory was untenable? What is the foundation of the theory that animal heat is evolved by the nervous system?

the lungs of a decapitated animal, the color of the blood was changed from purple to red, and carbonic acid emitted as usual; but that this animal grew cold more rapidly than another decapitated animal of the same kind which lay untouched. It is obvious that this result would follow unless heat was evolved by the artificial respiration, because the air forced into the lungs would abstract the heat of the animal.

686. "Were these experiments rigidly exact," says Dr. Turner, "they would lead to the opinion that no caloric is evolved by the mere process of arterialization. This inference can not, however, be admitted, for two reasons: First, because other physiologists, in repeating the experiments of Brodie, have found that the process of cooling is retarded by artificial respiration; and secondly, because it is difficult to conceive why the formation of carbonic acid, which uniformly gives rise to increase of temperature in other cases, should not be attended, within the animal body, with similar results. It may hence be inferred, that this is one of the sources of animal heat."

In respect to the influence of the nervous system over the development of animal temperature, there is no doubt but considerable effects may be safely attributed to this cause. But in what manner the heat is evolved, is perhaps uncertain.

687. THE CAUSE OF ANIMAL HEAT NOT ASCERTAINED.—In conclusion we may remark, that the subject of animal temperature has excited the attention, and has been made an object of experiment and research among philosophers and physiologists in all ages, and that many ingenious and some plausible theories have been invented and detailed, in order to give satisfactory explanation of its cause. The theory of Dr. Crawford, among these, was perhaps the most plausible, and certainly the most philosophical and beautiful. But we have seen, that the leading facts on which it was founded, have been proved by his successors not to be true, and therefore the theory itself can not be maintained. That the oxygen of the atmosphere is one of the causes of animal heat can not be doubted, from the facts, that no animal can live without it, and that the heat of animals is in some proportion to the quantity of this principle consumed.

But as this principle can have no effect, except through the

If heat were not evolved by artificial respiration, why should this process cool the animal rapidly? What are Dr. Turner's two reasons for supposing that Mr. Brodie's experiments are not conclusive, that heat is not evolved by respiration? Is it probable that the nerves affect the temperature of the animal? What is said in conclusion on this subject?

lungs, if it is admitted that heat is evolved by its action there, there is still much difficulty in explaining either why the lungs are not constantly at a higher temperature than the other parts of the system, or if they were, how the heat could be conveyed to the other parts, from its fountain.

On the whole, it appears that the cause of animal heat is one of the arcana of nature, into which man has not yet been permitted to look, and therefore, we must be contented at present to attribute it to the *vital principle.*

TEMPERATURE OF THE BLOOD, AND NUMBER OF PULSATIONS AND RESPIRATIONS IN DIFFERENT ANIMALS, IN A MINUTE.

	Temperature. Fah.	Pulsations.	Respirations.
In the pigeon, ...	107.6°	136	34
Common fowl, . . .	106.7°	140	30
Duck, ...	108.5°	170	21
Raven, ...	108.5°	110	21
Lark, ...	117.2°	200	22
Monkey, ...	95.9°	90	30
Guinea pig, ...	100.4°	140	36
Dog, ...	99.3°	90	28
Cat, ...	101.3°	100	24
Goat, ...	102.5°	84	24
Hare, ...	100.4°	120	36
Horse, ...	98.2°	56	16
Man, ...	98.6°	72	18

The above, from Liebig's Chemistry, is supposed to represent the average temperature, and the number of pulsations and respirations of the animals named, while in health, and in as quiet a condition as possible. It will be observed that those animals which respire most frequently, and consequently consume most oxygen, have generally the highest temperatures. Thus, the birds have the most frequent respirations and pulsations, and also the greatest degrees of heat, while man and the horse have the smallest number of respirations, and a corresponding low temperature.

CHLOROFORM.

688. This is a substance administered by breathing, in the form of gas, for the purpose of depriving patients of feeling, who

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Has there been any theory proposed which accounts satisfactorily for the cause of animal heat? To what is it said must we at present attribute the cause of animal heat? What is said of the number of respirations, and the temperature of animals?

are to undergo surgical operations. It is called an *anæsthenic* agent, from the Greek *anæsthesia*, signifying, loss of the sense of touch. The person who first administered any agent, in the form of vapor, or gas, for this purpose, it is believed by many, was Dr. Horace Wells, of Hartford, Connecticut, in 1844.

The agent which Dr. Wells administered, appears to have been the *nitrous oxide gas*, the effects of which have already been described. Afterward, it appears that the vapor of sulphuric ether was given by Dr. Morton, of Boston, for the same purpose. On this subject, it is well known that there exists a controversy, the question being, whether Dr. Wells or Dr. Morton first employed an anæsthetic agent for the purpose of depriving patients of feeling during painful operations. Into this controversy, it is here neither our duty or purpose to enter, the subject only requiring that the above explanations should be made, that it might be properly understood.

689. MANUFACTURE OF CHLOROFORM.—At present, neither the nitrous oxide, nor the vapor of ether, are in common use for the purpose in question, but, as stated above, an article called *chloroform* is administered, as a sense-destroying agent. This is made by chemists, and kept on hand as a medicine by all regular apothecaries, and is employed by many as a common remedy for pain, whether of body or mind. It should, however, be used with caution, and only with the advice of a physician, who should always administer it with his own hands, since many instances of death have been the result of its improper use.

One mode of preparing chloroform is as follows: Take *chlorinated lime*, (chloride of lime,) ten pounds; *water*, three and a half gallons; *alcohol*, two pints. First mix the lime and water, and then with these mix the alcohol. This mixture is distilled in a copper vessel, into a refrigerator, with a heat not exceeding 176 degrees. The liquid so obtained is colorless and transparent, it is not inflammable; has an etherial odor, to many persons quite pleasant.

690. HOW EMPLOYED.—When taken internally, in small doses, it acts as a sedative and narcotic. In cases of gangrene and cancer, it has been applied externally to the diseased parts. But it is more generally employed by inhalation. For this purpose, a small quantity, as half an ounce, is poured on a cloth, and held to the nose. Its effects, when taken in this way, differ greatly on different persons; but more commonly, they are, coma, relaxation of the muscles, slow respiration, upturning of the eyes, and total insensibility.

PART IV.

CHAPTER XXXVI.

ANALYTICAL CHEMISTRY.

691. To enter into a detailed account of experimental and analytical chemistry, is altogether inconsistent with the design and limits of the present work. My sole object in this department is to give a few concise directions for conducting some of the more common analytical processes; and in order to render them more generally useful, I shall give examples of the analysis of mixed gases, of minerals, and of mineral waters.

ANALYSIS OF MIXED GASES.

692. Analysis of gaseous mixtures containing oxygen.—Of the various processes by which oxygen gas may be withdrawn from gaseous mixtures, and its quantity determined, none are so convenient and precise as the method by means of hydrogen gas. In performing this analysis, a portion of atmospheric air is carefully measured in a graduated tube, and mixed with a quantity of hydrogen, which is rather more than sufficient for uniting with all the oxygen present. The mixture is then introduced into a strong glass tube called Volta's eudiometer, and is inflamed by the electric spark, the aperture of the tube being closed by the thumb at the moment of detonation. The total diminution in volume, divided by three, indicates the quantity of oxygen originally contained in the mixture. This operation may be performed in a trough either of water or mercury.

Instead of electricity, spongy platinum (page 163) may be employed for causing the union of oxygen and hydrogen gases; and, while its indications are very precise, it has the advantage of producing the effect gradually, and without detonation. The most convenient mode of employing it with this intention is the following: A mixture of spongy platinum and pipe-clay, in the proportion of about three parts of the former to one of the latter, is made into a paste with water, and then rolled between the fingers into a globular form. In order to preserve the spongy texture of the platinum, a little muriate of ammonia is mixed with the paste; and when the ball has become dry, it is cautiously ignited at the flame of a spirit-lamp. The sal ammoniac, escaping from all parts of the mass, gives a degree of porosity which is peculiarly favorable to its action. The ball, thus prepared, should be protected from dust, and be heated to redness just before being used. To insure accuracy, the hydrogen employed should be kept over mercury for a few hours in contact with a spongy platinum ball and a piece of caustic potash. The first deprives it of traces of oxygen, which it commonly contains, and the second of moisture and sulphureted hydrogen. The analysis must be performed in a mercurial trough. The time required for completely removing the oxygen depends on the diameter of the tube. If the mixture is contained in a very narrow tube, the diminution does not arrive at its full extent in less than twenty minutes or half an hour; while in a vessel of an inch in diameter, the effect is complete in the course of five minutes.

693. MODE OF DETERMINING THE QUANTITY OF NITROGEN IN GASEOUS MIXTURES.—As atmospheric air, which has been deprived of moisture and carbonic acid, consists of oxygen and nitrogen only, the proportion of the latter is, of course, known as soon as that of the former is determined. The only method, indeed, by which chemists are enabled to estimate the quantity of this gas, is by withdrawing the other gaseous substances with which the nitrogen is mixed.

694. MODE OF DETERMINING THE QUANTITY OF CARBONIC ACID IN GASEOUS MIXTURES.—When carbonic acid is the only acid gas which is present, as happens in atmospheric air, in the ultimate analysis of organic compounds, and in most other analogous researches, the process for determining the quantity of carbonic acid is exceedingly simple; for it consists merely in absorbing that gas by lime water, or a solution of caustic potash. This is easily done, in the course of a few minutes, in an ordinary graduated tube; or it may be effected, almost instantaneously, by agitating the gaseous mixture with the alkaline solution, in Hope's eudiometer. This apparatus is formed of two parts; a bottle capable of containing about twenty drams of fluid, and furnished with a well-ground stopper; and a tube of the capacity of one cubic inch, divided into 100 equal parts, and accurately fitted, by grinding, to the neck of

the bottle. The tube, full of gas, is fixed into the bottle previously filled with lime water, and its contents are briskly agitated. The stopper is then withdrawn under water, when a portion of liquid rushes into the tube, supplying the place of the gas which has disappeared; and the process is afterward repeated, as long as any absorption ensues.

695. The eudiometer of Dr. Hope was originally designed for analyzing air or other similar mixtures, the bottle being filled with a solution of the hydro-sulphuret of potassa, or lime, or some liquid capable of absorbing oxygen. To the employment of this apparatus it has been objected, that the absorption is rendered slow by the partial vacuum which is continually taking place within it, an inconvenience particularly felt toward the close of the process, in consequence of the eudiometric liquor being diluted by the admission of water. To remedy this defect, Dr. Henry has substituted a bottle of elastic gum for that of glass, by which contrivance no vacuum can occur. From the improved method of analyzing air, however, this instrument is now rarely employed in eudiometry; but it may be used with advantage for absorbing carbonic acid of similar gases, and is particularly useful for the purpose of demonstration.

696. MODE OF ANALYZING MIXTURES OF HYDROGEN AND OTHER INFLAMMABLE GASES.—When hydrogen is mixed with nitrogen, air, or other similar gaseous mixtures, its quantity is easily ascertained by causing it to combine with oxygen, either by means of platinum sponge, or the electric spark. If, instead of hydrogen, any other combustible substance, such as carbonic oxide, light carbureted hydrogen, or olefiant gas, is mixed with nitrogen, the analysis is easily effected by adding a sufficient quantity of oxygen, and detonating the mixture by electricity. The diminution in volume indicates the quantity of hydrogen contained in the gas, and from the carbonic acid, which may then be removed by an alkali, the quantity of carbon is inferred.

When olefiant gas is mixed with other inflammable gases, its quantity is easily determined by an elegant and simple process proposed by Dr. Henry. It consists in mixing 100 measures, or any convenient quantity of the gaseous mixture, with an equal volume of chlorine, in a vessel covered with a piece of cloth, or paper, so as to protect it from light; and after an interval of about ten minutes, the excess of chlorine is removed by lime water, or potassa. The loss experienced by the gas to be analyzed, indicates the exact quantity of olefiant gas which it had contained.

In mixtures of hydrogen, carbureted hydrogen, and carbonic oxide, the analytic process is exceedingly difficult and complicated, and requires all the resources of the most refined chemical knowledge, and all the address of an experienced analyst. The most recent information on this subject will be found in Dr. Henry's Essay, in the Philosophical Transactions for 1824.

ANALYSIS OF MINERALS.

697. As the very extensive nature of this department of analytical chemistry renders a selection necessary, I shall confine my remarks solely to the analysis of those earthy minerals with which the beginner usually commences his labors. The most common constituents of these compounds are silica, alumina, iron, manganese, lime, magnesia, potassa, soda, and the carbonic and sulphuric acids; and I shall, therefore, endeavor to give short directions for determining the quantity of each of these substances.

In attempting to separate two or more fixed principles from each other, the first object of the analytical chemist is to bring them into a state of solution. If they are soluble in water, this fluid is preferred to every other menstruum, but if not, an acid, or any convenient solvent may be employed. In many instances, however, the substance to be analyzed resists the action even of the acids, and in that case, the following method is adopted: The compound is first crushed by means of a hammer, or a steel mortar, and is afterward reduced to an impalpable powder in a mortar of agate; it is then intimately mixed with three, four, or more times its weight of potassa, soda, baryta, or their carbonates; and lastly, the mixture is exposed in a crucible of silver, or platinum, to a strong heat. During the operation, the alkali combines with one or more of the constituents of the mineral; and, consequently, its elements being disunited, it no longer resists the action of the acids.

698. ANALYSIS OF MARBLE OR CARBONATE OF LIME.—This analysis is easily made by exposing a known quantity of marble, for about half an hour, to a full white heat, by which means the carbonic acid gas is entirely expelled, so that by the loss in weight the quantity of each ingredient, supposing the marble to have been pure, is at once determined. In order to

ascertain that the whole loss is owing to the escape of carbonic acid, the quality of this gas may be determined by a comparative analysis. Into a small flask, containing muriatic acid, diluted with two or three parts of water, a known quantity of marble is gradually added, the flask being inclined to one side in order to prevent the fluid from being flung out of the vessel during the effervescence. The diminution in weight experienced by the flask and its contents, indicates the quantity of carbonic acid which has been expelled.

Should the carbonate suffer a greater loss in the fire than when decomposed by an acid, it will most probably be found to contain water. This may be ascertained by heating a piece of it to redness, in a glass tube, the sides of which will be bedewed with moisture, if water is present. Its quantity may be determined by causing the watery vapor to pass through a weighed tube filled with fragments of the chloride of calcium, (muriate of lime,) by which the moisture is absorbed.

699. SEPARATION OF LIME AND MAGNESIA.—The more common kinds of carbonate of lime frequently contain traces of silicious and aluminous earths, in consequence of which, they are not completely dissolved in dilute muriatic acid. A very frequent source of impurity is the carbonate of magnesia, which is often present in such quantity that it forms a peculiar compound called *magnesian limestone.* The analysis of this substance, so far as respects carbonic acid, is the same as that of marble. The separation of the two earths may be conveniently effected in the following manner: The solution of the mineral in muriatic acid is evaporated to perfect dryness, in a flat dish, or *capsule* of porcelain, and after redissolving the residuum, in a moderate quantity of distilled water, a solution of the oxalate of ammonia is added as long as a precipitate ensues. The oxalate of lime is then allowed to subside, collected on a filter, converted into quicklime by a white heat, and weighed; or the oxalate may be decomposed by a red heat, the carbonate resolved into the sulphate of lime by sulphuric acid, and the excess of acid expelled by a temperature of ignition. To the filtered liquid containing the magnesia, an excess of carbonate of ammonia, and then phosphate of soda is added, when the magnesia, in the form of the ammoniaco-phosphate, is precipitated. Of this precipitate, heated to redness, 100 parts correspond to 40 of pure magnesia. (*Murray.*)

700. EARTHY SULPHATES.—The most abundant of the earthy

sulphates, is that of lime. The analysis of this compound is easily effected. By boiling it for fifteen or twenty minutes with a solution of twice its weight of the carbonate of soda, double decomposition ensues; and the carbonate of lime, after being collected on a filter and washed with hot water, is either heated to low redness, to expel the water, and weighed, or at once reduced to quicklime by a white heat. Of the dry carbonate, fifty parts correspond to twenty-eight of lime. The alkaline solution is acidulated with muriatic acid, and the sulphuric acid thrown down by the muriate of baryta. From the sulphate of this earth, collected and dried at a red heat, the quantity of acid may easily be estimated.

The method of analyzing the sulphates of strontia and baryta is somewhat different. As these salts are difficult of decomposition in the moist way, the following process is adopted: The sulphate, in fine powder, is mixed with three times its weight of the carbonate of soda, and the mixture is heated to redness in a platina crucible, for the space of half an hour. The ignited mass is then digested in hot water, and the insoluble earthy carbonate collected on a filter. The other parts of the process are the same as the foregoing.

701. MODE OF ANALYZING COMPOUNDS OF SILICA, ALUMINA, AND IRON.—Minerals, thus constituted, are decomposed by an alkaline carbonate, potash, or soda, at a red heat, in the same manner as the sulphate of baryta. The mixture is afterward digested in dilute muriatic acid, by which means all the ingredients of the mineral, if the decomposition is complete, are dissolved. The solution is next evaporated to dryness, the heat being carefully regulated toward the close of the process, in order to prevent any of the chloride of iron, the volatility of which is considerable, from being dissipated in vapor. By this operation, the silica, though previously held in solution by the acid, is entirely deprived of its solubility; so that on digesting the dry mass in water, acidulated with muriatic acid, the alumina and iron are taken up, and the silica is left in a state of purity. The siliceous earth, after subsiding, is collected on a filter, carefully edulcorated, heated to redness, and weighed.

To the clear liquid containing iron and alumina, a considerable excess of a solution of pure potassa is added; so as not only to throw down these oxides, but to dissolve the alumina. The peroxide of iron is then collected on a filter, edulcorated carefully until the washings cease to have an alkaline reaction, and is well dried on a sand bath. Of this hydrated peroxide, forty-nine parts contain forty of the anhydrous peroxide of iron. But the most accurate mode of determining its quantity is by expelling the water by a red heat. This operation, however, should be done with care; since any adhering particles of paper, or other combustible matter, would bring the iron into the state of black oxide, a change which is known to have occurred by the iron being attracted by a magnet.

To procure the alumina, the liquid in which it is dissolved is boiled with sal-ammoniac, when the muriatic acid unites with the potassa, the volatile alkali is dissipated in vâpor, and the alumina subsides. As soon as the solution is thus rendered neutral, the hydrous alumina is collected on a filter, dried by exposure to a white heat, and quickly weighed after removal from the fire.

702. SEPARATION OF IRON AND MANGANESE.—A compound of these metals, or their oxide, may be dissolved in muriatic acid. If the iron is in a large proportion, compared with the manganese, the following process may be adopted with advantage: To the cold solution, considerably diluted with water, and acidulated with muriatic acid, carbonate of soda is gradually added, and the liquid is briskly stirred with a glass rod, during the effervescence, in order that it may become highly charged with carbonic acid. By neutralizing the solution in this manner, it at length attains a point at which the peroxide of iron is entirely deposited, leaving the liquid colorless; while the manganese, by aid of the free carbonic acid, is kept in solution. The iron, after subsiding, is collected on a filter, and its quantity determined in the usual manner. The filtered liquid is then boiled with an excess of the carbonate of soda; and the precipitated carbonate of manganese is collected, heated to low redness in an open crucible, by which it is converted into the brown oxide, and weighed. This method is one of some delicacy; but in skillful hands, it affords a very accurate result. It may also be employed for separating iron from magnesia and lime as well as from manganese.

703. BY SUCCINATE OF AMMONIA.—But if the proportion of iron is small, compared with that of manganese, the best mode of separating it is by the succinate of ammonia or soda, prepared by neutralizing a solution of succinc acid with either of those alkalies. That this process should succeed, it is necessary that the iron be wholly in the state of peroxide, that the

solution be exactly neutral, which may easily be insured by the cautious use of ammonia, and that the reddish-brown colored succinate of iron be washed with cold water. Of this succinate, well dried at a temperature of 212 degrees F., 90 parts correspond to 40 of the peroxide. From the filtered liquid, the manganese may be precipitated at a boiling temperature by carbonate of soda, and its quantity determined in the way above mentioned. The benzoate may be substituted for the succinate of ammonia in the preceding process.

It may be stated as a general rule, that whenever it is intended to precipitate iron by means of the alkalies, the succinates, or benzoates, it is essential that this metal be in the maximum of oxidation. It is easily brought into this state by digestion with a little nitric acid.

704. SEPARATION OF MANGANESE FROM LIME AND MAGNESIA.—If the quantity of the former be proportionally small, it is precipitated as a sulphuret by the hydrosulphuret of ammonia or potassa. This sulphuret is then dissolved in muriatic acid, and the manganese thrown down as usual by means of an alkali. But if the manganese be the chief ingredient, the best method is to precipitate it at once, together with the two earths, by a fixed alkaline carbonate, at a boiling temperature. The precipitate, after being exposed to a low red heat and weighed, is put into cold water, acidulated with a drop or two of nitric acid, when the lime and magnesia will be slowly dissolved with effervescence. Should a trace of the manganese be likewise taken up, it may easily be thrown down by the hydrosulphuret of ammonia.

705. MODE OF ANALYZING AN EARTHY MINERAL CONTAINING SILICA, IRON, ALUMINA, MANGANESE, LIME, AND MAGNESIA.—The mineral, reduced to a fine powder, is ignited with three or four times its weight of the carbonate of potassa or soda, the mass is taken up in dilute muriatic acid, and the silica separated in the way already described. To the solution, thus freed from silica and duly acidulated, carbonate of soda is gradually added, so as to charge the liquid with carbonic acid, as in the analysis of iron and manganese. In this manner the iron and alumina are alone precipitated, substances which may be separated from each other by means of pure potassa. The manganese, lime, and magnesia, may be determined by the processes already described.

706. ANALYSIS OF MINERALS CONTAINING A FIXED ALKALI.—When the object is to determine the quantity of a fixed

alkali, such as potassa or soda, it is necessary to abstain from the employment of these reagents in the analysis itself; and the beginner will do well to devote his attention to the alkaline ingredients only. On this supposition, he will proceed in the following manner: The mineral is reduced to a very fine powder, mixed intimately with six times its weight of the artificial carbonate of baryta, and exposed for an hour to a white heat. The ignited mass is dissolved in dilute muriatic acid, and the solution evaporated to perfect dryness. The soluble parts are taken up in hot water; an excess of the carbonate of ammonia is added; and the insoluble matters, consisting of silica, carbonate of baryta, and all the constituents of the mineral, excepting the fixed alkali, are collected on a filter. The clear solution is evaporated to dryness in a porcelain capsule, and the dry mass is heated to redness in a crucible of platinum, in order to expel the salts of ammonia. The residue is the chloride of potassium or sodium.

In this analysis, it generally happens that traces of manganese, and sometimes of iron, escape precipitation in the first part of the process; and, in that case, they should be thrown down by the hydrosulphuret of ammonia. If neither lime nor magnesia is present, the alumina, iron, and manganese, may be separated by pure ammonia, and the baryta subsequently removed by the carbonate of that alkali. By this method the carbonate of baryta is recovered in a pure state, and may be reserved for another analysis. The baryta may also be thrown down, as a sulphate, by sulphuric acid, in which case, the soda or potassa is procured in combination with that acid.

The analysis is attended with considerable inconvenience, when magnesia happens to be present, because this earth is not completely precipitated, either by ammonia or its carbonate; and, therefore, some of it remains with the fixed alkali. The best mode with which I am acquainted for effecting its separation is the following: The carbonate of ammonia is first added, and the phosphoric acid is dropped into the liquid, until all the magnesia is thrown down in the form of the ammoniaco-magnesian phosphate. The excess of phosphoric acid is afterward removed by the acetate of lead, and that of lead by sulphureted hydrogen. The acetate of the alkali is then brought to dryness, ignited, and by the addition of sulphate of ammonia is converted into a sulphate.

707. Process of filtration.—In the preceding account, several operations have been alluded to, which, from their im-

portance, deserve more particular mention. The process of filtering, for example, is one on which the success of analysis materially depends. Filtration is effected by means of a glass funnel, into which a filter, made of white bibulous paper, is inserted. For researches of delicacy, the filter, before being used, is macerated for a day or two in water, acidulated with nitric acid, in order to dissolve lime and other substances contained in common paper, and it is afterward washed with hot water, till every trace of acid is removed. It is next dried at 212 degrees, or any fixed temperature insufficient to decompose it, and then carefully weighed, the weight being marked upon it with a pencil. As dry paper absorbs hygrometic moisture rapidly from the atmosphere, the filter, while being weighed, should be inclosed in a light box made for the purpose. When a precipitate is collected on a filter, it is washed with pure water until every trace of the original liquid is removed. It is subsequently dried and weighed as before, and the weight of the paper subtracted from the combined weight of the filter and precipitate. The trouble of weighing the filter may sometimes be dispensed with. Some substances, such as silica, alumina, and lime, which are not decomposed when heated with combustible matter, may be put into a crucible while yet contained in the filter, the paper being set on fire before it is placed in the furnace. In these instances, the ash from the paper, the average weight of which is determined by previous experiments, must be subtracted from the weight of the heated mass.

The tests commonly employed in ascertaining the acidity or alkalinity of liquids are litmus and turmeric paper. The former is made by digesting litmus, reduced to a fine powder, in a small quantity of water, and painting with it white paper which is free from alum. The turmeric paper is made in a similar manner; but the most convenient test of alkalinity is litmus paper reddened by a dilute acid.

ANALYSIS OF MINERAL WATERS.

708. Rain water, collected in clean vessels in the country, or freshly fallen snow, when melted, affords the purest kind of water which can be procured without having recourse to distillation. The water obtained from these sources, however, is not absolutely pure, but contains a portion of carbonic acid and air, absorbed from the atmosphere. It is remarkable that this

air is very rich in oxygen. That procured from snow water by boiling, was found by Gay Lussac and Humboldt to contain 34.8, and that from rain water 32 per cent. of oxygen gas. From the powerfully solvent properties of water, this fluid no sooner reaches the ground and percolates through the soil, than it dissolves some of the substances which it meets with in its passage. Under common circumstances, it takes up so small a portion of foreign matter that its sensible properties are not materially affected, and in this state it gives rise to *spring*, *well*, and *river* water. Sometimes, on the contrary, it becomes so strongly impregnated with saline and other substances, that it acquires a peculiar flavor, and is thus rendered unfit for domestic uses. It is then known by the name of *mineral water*.

709. SPRING WATER.—The composition of spring water is dependent on the nature of the soil through which it flows. If it has filtered through primitive strata, such as quartz rock, granite, and the like, it is in general very pure; but if it meets with limestone or gypsum in its passage, a portion of these salts is dissolved, and communicates the property called *hardness*. Hard water is characterized by decomposing soap, the lime of the former yielding an insoluble compound with the oil of the latter. If this defect is owing to the presence of the carbonate of lime, it is easily remedied by boiling, when free carbonic acid is expelled, and the insoluble carbonate of lime subsides. If sulphate of lime is present, the addition of a little carbonate of soda, by precipitating the lime, converts the hard into soft water. Besides these ingredients, the muriates of lime and soda are frequently contained in spring water.

Spring water, in consequence of its saline impregnation, is frequently unfit for chemical purposes, and on these occasions distilled water is employed. Distillation may be performed on a small scale by means of a retort, in the body of which water is made to boil, while the condensed vapor is received in a glass flask, called a *recipient*, which is adapted to its beak or open extremity. This process is more conveniently conducted, however, by means of a still.

710. ARRANGEMENT OF MINERAL WATERS.—The different kinds of mineral water may be conveniently arranged for the purpose of description in the four divisions of carbonated, chalybeate, sulphurous, and saline springs.

The carbonated springs of which those of Seltzer, Spa, Pyrmont, Ballston, and Carlsbad, are the most celebrated, and are distinguished by containing a considerable quantity of free carbonic acid, owing to the escape of which they sparkle when poured from one vessel into another. They communicate a red tint to litmus paper before, but not after being boiled, and the redness disappears on exposure to the air. Mixed with a sufficient quantity of lime water, they become turbid from the deposition of carbonate of lime. They frequently contain the carbonate of lime, magnesia, and iron, in consequence of the facility with which these salts are dissolved by water charged with carbonic acid.

The best mode of determining the quantity of carbonic acid is by heating a portion of the water in a flask, and receiving the carbonic acid by means of a bent tube, in a graduated jar filled with mercury.

711. CHALYBEATE WATERS. — The chalybeate waters are characterized by a strong styptic inky taste, and by striking a black color with the infusion of gall-nuts. The iron is sometimes combined with the muriatic or sulphuric acid; but most frequently it is in the form of a carbonate of the protoxide, held in a solution by free carbonic acid. On exposure to the air, the protoxide is oxidized, and the hydrated peroxide subsides, causing the ochreous deposit, so commonly observed in the vicinity of chalybeate springs.

To ascertain the quantity of iron contained in a mineral water, a known weight of it is concentrated by evaporation, and the iron brought to the state of peroxide by means of nitric acid. The peroxide is then precipitated by an alkali and weighed; and if lime and magnesia are present, it may be separated from those earths by the process described in the last section.

Chalybeate waters are by no means uncommon; but the most noted in Britain are those of Tunbridge, Cheltenham, and Brighton. The Bath water also contains a small quantity of iron.

712. SULPHUROUS WATERS. — The sulphurous waters, of which the springs of Aix la Chapelle, Harrowgate, and Moffat afford examples, contain sulphureted hydrogen, and are easily recognized by their odor, and by causing a brown precipitate with a salt of lead or silver. The gas is readily expelled by boiling, and its quantity may be inferred by transmitting it through a solution of the acetate of lead, and weighing the sulphuret which is generated.

713. SALINE WATERS.—Those mineral springs are called saline which do not belong to either of the preceding divisions. The salts which are most frequently contained in these waters, are the sulphates, muriates, and carbonates of lime, magnesia, and soda. Potassa sometimes exists in them, and Berzelius has found lithia in the spring at Carlsbad. It has lately been discovered that the presence of hydriodic acid in small quantity is not infrequent. As examples of saline water, may be enumerated the springs of Epsom, Cheltenham, Bath, Bristol, Bareges, Buxton, Pithcaithly, Tœplitz, Ballston, and Saratoga.

The first object in examining a saline spring is to determine the nature of its ingredients. Muriatic acid is detected by the nitrate of silver, and the sulphuric acid by muriate of baryta; and if an alkaline carbonate be present, the precipitate occasioned by either of these tests will contain a carbonate of silver or baryta. The presence of lime and magnesia may be discovered, the former by the oxalate of lime, and the latter by carbonate of ammonia and the phosphoric acid. Potassa is known by the action of the muriate of platinum. To detect soda, the water should be evaporated to dryness, the deliquescent salts removed by alcohol, and the matter insoluble in that menstruum taken up by a small quantity of water, and be allowed to crystallize by spontaneous evaporation. The salt of soda may then be recognized by the rich yellow color which it communicates to flame. If the presence of hydriodic acid is suspected, the solution is brought to dryness, the soluble parts dissolved in two or three drams of a cold solution of starch, and strong sulphuric acid gradually added.

714. MODE OF FINDING THE QUANTITY.—Having thus ascertained the nature of the saline ingredients, their quantity may be determined by evaporating a pint of water to dryness, heating to low redness, and weighing the residue. In order to make an exact analysis, a given quantity of the mineral water is concentrated in an evaporating basin, as far as can be done without causing either precipitation or crystallization, and the residual liquid is divided into two equal parts. From one portion the sulphuric and carbonic acids are thrown down by the nitrate of baryta, and after collecting the precipitate on a filter, the muriatic acid is precipitated by the nitrate of silver. The mixed sulphate and carbonate is exposed to a low red heat, and weighed; and the latter is then dissolved by dilute muriatic acid, and its quantity determined by weighing the sulphate.

The chloride of silver, of which 146 parts correspond to 37 of muriatic acid, is fused in a platinum spoon or crucible, in order to render it quite free from moisture. To the other half of the concentrated mineral water, oxalate of lime is added for the purpose of precipitating the lime; and the magnesia is afterward thrown down as the ammoniaco-phosphate, by means of the carbonate of ammonia and phosphoric acid. Having thus determined the weight of each of the fixed ingredients, excepting the soda, the loss of course gives the quantity of that alkali; or it may be procured in a separate state by the process described in the foregoing section.

715. IN WHAT STATE COMBINED.—The individual constituents of the water being known, it remains to determine the state in which they were originally combined. In a mineral water containing sulphuric and muriatic acids, lime, and soda, it is obvious that three cases are possible. The liquid may contain sulphate of lime and muriate of soda, muriate of lime and sulphate of soda, or each acid may be distributed between both the bases. It was at one time supposed that the lime must be in combination with sulphuric acid, because the sulphate of that earth is left, when the water is evaporated to dryness. This, however, by no means follows. In whatever state the lime may exist in the original spring, gypsum will be generated as soon as the concentration reaches that degree at which sulphate of lime can not be held in solution. The late Dr. Murray,* who treated this question with much sagacity, observes, that some mineral waters, which contain the four principles above mentioned, possess higher medicinal virtues than can be justly ascribed to the presence of sulphate of lime and muriate of soda. He advances the opinion, that alkaline bases are united in mineral waters with those acids with which they form the most soluble compounds, and that the insoluble salts obtained by evaporation are merely products. He therefore proposes to arrange the substances determined by analysis according to this supposition. To this practice there is no objection; but it is probable that each acid is rather distributed between several bases, than combined exclusively with one of them.

716. SEA WATER.—Sea water may be regarded as one of the saline mineral waters. Its taste is disagreeably bitter and saline, and its fixed constituents amount to about three

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* Philosophical Transactions of Edinburgh, vol. vii.

cent. Its specific gravity varies from 1.0269 to 1.0285; and it freezes at about 28.5 degrees F. According to the analysis of Dr. Murray, 10,000 parts of water from the Firth of Forth contain 220.01 parts of common salt, 33.16 of sulphate of soda, 42.08 of muriate of magnesia, and 7.84 of muriate of lime. Dr. Wollaston has detected potassa in sea water, and it likewise contains small quantities of the hydriodic and iodic and hydrobromic acids.

717. THE DEAD SEA.—The water of the Dead Sea has a far stronger saline impregnation than sea water, containing one-fourth of its weight of solid matter. It has a peculiarly bitter, saline, and pungent taste, and its specific gravity is 1.211. According to the analysis of Dr. Marcet, 100 parts of it are composed of muriate of magnesia, 10.246, muriate of soda, 10.36, muriate of lime, 3.92, and sulphate of lime, 0.054. In the river Jordan, which flows into the Dead Sea, Dr. Marcet discovered the same principles as in the lake itself.—*Turner's Chemistry.*

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